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A COMPREHENSIVE EVALUATION of the PROPOSED WIVENHOE DAM on the BRISBANE RIVER

AN EXAMINATION OF THE ECONOMIC, FINANCIAL, SOCIAL AND ENVIRONMENTAL EFFECTS

CO-ORDINATOR-GENERAL'S DEPARTMENT · QUEENSLAND ·

PREPARED FOR THE
CO-ORDINATOR-GENERAL'S DEPARTMENT
JUNE 1977

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A COMPREHENSIVE EVALUATION OF THE PROPOSED WIVENHOE DAM ON THE BRISBANE RIVER

An examination of the Economic, Financial, Social and Environmental effects considered as likely to occur as a result of the construction of the proposed Dam and associated works and suggested measures that might be taken to mitigate the possible adverse effects

A REPORT PREPARED FOR THE

CO-ORDINATOR-GENERAL'S DEPARTMENT

by

T.J. GRIGG, B.E.(Hons.), B.Econ.

Lecturer, Dept. Civil Engineering,
University of Queensland

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This report draws heavily on the work of others. All of the basic data has been provided by a number of State Government Departments, by the Snowy Mountains Engineering Corporation or by the Brisbane City Council. Sections 2, 3, 4, 5, 6, 7, 8 and 9 are in a large part summaries of information contained in reports published by various Government Departments or Authorities, in papers published by State Government or Brisbane City Council officers and in unpublished reports and memoranda by State Government Departments and the Brisbane City Council. All the Appendices, except numbers 6 and 7, were prepared by others. Sections 10, 11 and 12, and Appendix 7 rely on basic data provided by others but the analysis in each section and the conclusions are my own.

Every effort has been made to faithfully reference the use of all material provided by others and to accurately summarise the information provided in the reports and memoranda. The active assistance of officers of the Brisbane City Council, the Irrigation and Water Supply Commission and the Co-ordinator-General's Department is acknowledged.

Particular thanks are due to the typists who have had the unenviable task of typing the report and the many earlier drafts. I appreciated very much the opportunity given to me,by the Co-ordinator-General, to produce this report.

INTRODUCTION

Historical Background

In 1971, the Queensland State Government decided that, when the capacity of the North Pine River Dam was fully utilised, the next urban water storage for the Brisbane City Conurbation should be a dam built on the Brisbane River at Wivenhoe, a little upstream of the junction of Lockyer Creek with the River. A dam on the Brisbane River at Wivenhoe was approved, instead of a dam on the Albert River at Wolffdene, because the storage available for urban water supply was larger, the unit cost of water was a little lower and because of the possibility of building a major flood storage in the dam to mitigate flooding in the urban areas of Brisbane and Ipswich.

The State Government asked the Federal Government for financial assistance towards the cost of construction of the dam. The Federal Government requested that a comprehensive investigation should be undertaken into the economic, social and environmental effects due to the construction of the dam. Following the January 1974 floods in the Brisbane River, the Snowy Mountains Engineering Corporation carried out an assessment of the damage caused by floods of different heights in the urbanised area of the lower Brisbane Valley so that up to date damage figures would be available for the assessment of the effectiveness of the proposed flood storage.

Before the evaluation could be completed, the hydrology of the Brisbane River had to be re-examined, the size of the flood compartment in the dam had to be determined, the preliminary design of the dam completed and the estimates of cost prepared. The necessary information was not available until late in 1976.

The "Report on Proposed Dam on the Brisbane River at Middle Creek or Alternatively Wivenhoe and Flood Mitigation for Brisbane and Ipswich" Co-ordinator-General's Department 1971, which recommended the construction of the dam, did examine in broad terms the flood mitigation effect of the dam and the impact on the natural environment in the area of the dam and the impact on the economic and social environment of Esk Shire. An investigation into the impact on the local natural environment which would result from the construction of the Pumped Storage Project was made at the time that the report recommending its construction was prepared.

The decision to build the project was made before this present evaluation was started. The evaluation necessarily had to rely on data that could only be available after the preliminary design of the project was well advanced. Land acquisition for large dam projects takes a number of years to complete and requires the expenditure of considerable funds. The adverse effect of the construction of the dam on the owners of land in the area to be flooded was recognised in the report mentioned above and acquisition and lease back procedures were adopted to minimise, as far as possible, the disruption. During the preliminary design stage a decision had to be made regarding the provision of a fish lift. This is discussed in the report.

The decision to build the Pumped Storage Hydro-electric Project was made in 1976. This project is located in the main on land acquired for the Wivenhoe Dam. The justification for this project has been made elsewhere. This report examines the effect of the Pumped Storage Hydro-electric Project on the local natural environment and on Wivenhoe Dam.

Purpose of the Report

The report aims to evaluate the economic, financial, social and environmental effects which arise as a result of the decision to build Wivenhoe Dam and its associated works.

Content of the Report

The report brings together, often in summary form only, the considerations that led to the decision to build Wivenhoe Dam and the Pumped Storage Hydro-electric Project. It also examines the effects likely to occur during and after the construction of the Dam and the effects that might occur if changes in water pricing policies were made, if floodway clearance and flood plain management policies in the urbanised areas were introduced and if a different cost allocation method to the one adopted was used. The Appendices provide more detailed information on certain matters discussed in the body of the report.

SUMMARY

In 1971 the Queensland Government decided that the next urban water supply storage for the Brisbane Conurbation would be sited at Wivenhoe A.M.T.D. 150 kilometres on the Brisbane River, 65 kilometres by road from Brisbane, just upstream of the junction with Lockyer Creek. The planned commissioning date of 1981/82 was subsequently decided upon. In 1976 the Government decided that a pumped storage hydro-electric scheme should be constructed using Wivenhoe Dam as its lower storage and that this scheme should produce peak load power in the winter of 1983.

Wivenhoe Dam will be a multi-purpose water storage facility of about 2.5 million megalitres capacity. About 1.14 million megalitres will be used as an urban water storage and about 1.4 million megalitres will be used for a flood storage. The stored water will also act as the lower pool of a pumped storage hydro-electric power generation scheme. The total surface area of the stored water surface will be about 10 700 hectares at full supply level and this 'lake' and its foreshores will provide a major recreational resource for the Moreton Region.

The construction of Wivenhoe Dam will result in the inundation of large areas of land upstream of the site. This will displace present land use in the area and will have an effect on the social and economic activity in the area, as well as an effect on the natural environment. There is a need to examine in some detail the likely effect of Wivenhoe Dam and its associated works on the natural, social and economic environment in terms of both favourable and adverse effects. Measures aimed at 'minimising' the adverse effects and 'maximising' the favourable effects need to be defined and these measures should become part of the proposal. As the Dam is a multi-purpose facility, a clear specification of guidelines for joint use to avoid conflict between users is required. This report is an attempt to address these concerns and issues.

The provision of the next water supply source for the Brisbane Conurbation is the primary purpose for which Wivenhoe Dam will be built. The water from the Dam will be needed in 1981/82 and the Dam should meet the demand for water until about 1995. In view of the limited surface water storages available in the Region after Wivenhoe Dam is built, changes in management and water pricing policies to encourage less waste in the use of water will be needed in the future. The cost of construction of Wivenhoe Dam will increase the unit cost of water in the Brisbane City distribution system.

Flood mitigation in the urbanised areas of the lower Brisbane Valley is another purpose for which the Dam is being built. The equivalent uniform annual flood damage in the flood plain in mid 1974 prices and with mid 1974 stage of development, excluding the effect of Wivenhoe Dam, has been assessed at \$6.18 million. The flood storage compartment provided in

the Dam will significantly reduce this level of damage but this benefit will only persist into the future if encroachment into hazardous areas of the flood plain can be stopped and if the development of less hazardous areas is restricted to flood tolerant uses. The best advantage of the flood mitigating potential of Wivenhoe Dam can only be obtained if complementary flood plain management policies are introduced by the Local Authorities in the urbanised areas of the Brisbane River flood plain. It would be necessary to acquire residential properties below the level adopted as the acceptable hazard level. The cost of this acquisition varies with the acceptable hazard level adopted, but the equivalent uniform annual flood damage avoided could be as high as $5 million if a combined 1 400 000 megalitres flood storage and a flood plain management strategy based on an acceptable hazard level is adopted.

The lake behind the Wivenhoe Dam will be used as the lower storage for a Pumped Storage Hydro-electric Project. The Pumped Storage project which will be built to use Wivenhoe Dam water will provide economical peak load power after commissioning in 1983. Only the water lost by evaporation and seepage in the upper Dam is lost to urban water supply.

The 300 kilometres of shoreline and the 10 700 hectares of water surface created by the Dam at full supply level will ensure that the Dam will develop into a much needed recreational resource in the Moreton Region. The extent of the recreational use will be determined by water quality requirements.

Adverse effects during construction, such as increased turbidity of the river water, etc., are not expected to be significant at the Mt. Crosby treatment works. The construction methods which will be adopted are designed to ensure the safety of the uncompleted dam during construction so that no failure of the uncompleted wall should occur.

Upstream of the Dam wall the area needed for urban water storage plus the area required as a flood margin will mean the total or partial acquisition of about 238 properties. If affected owners so request, their land is acquired earlier than needed and the property is leased back to them at low rentals until it is required. This allows owners to move into another income source when it suits them and provides an income during the transition period. The net value of production lost from the areas that will be used for the purposes of the Dam was estimated in 1970 to be about $0.5 million in 1970 money values. The reduction in local business revenue in Esk and Toogoolawah was estimated in 1970 to be about $1.8 million per year in 1970 money values. Unless the area acquired for the Dam can be levied for rates, Esk Shire Council will lose about 10% of its rate revenue. There will be a reduction in the population and labour force engaged in rural industry in Esk Shire and there will be some outmigration from the Shire as a result.

The ponded area behind the Dam will inundate some roads and services. About 69 kilometres of road, some under the control of the Main Roads Department, will need to be relocated. All relocated roads will be built at least to the standard of the road to be replaced and usually to a higher standard. The country traversed by the relocated roads has generally been cleared in the past for grazing, and no adverse effects on the existing natural environment and no measurable effects on water quality in the Dam are expected. No adverse effects are foreseen as a result of the relocation of Telecom, electricity and other services. All relocation costs will be borne by the project except that the Main Roads Department will bear the cost of upgrading roads under its control where a higher standard is adopted.

The Dam site and the inundated area have been extensively cleared in the past for grazing or agriculture. The remaining timber will be cleared within the inundated area. A small isolated patch of rain-forest will be extensively reduced by the construction of the powerhouse and the access channel. The rain-forest area is not unique, although similar patches left in the Brisbane Valley are few in number. Construction processes should be devised to do as little damage as possible.

The Dam will block the movement of sea mullet upstream. The cost of a fish lift is not justified in view of the uncertainty of its effectiveness and the small number of mullet involved. Stocking the Dam with a suitable fish could provide the recreational fishing now provided by the mullet in areas upstream of the Dam.

The Dam will inundate some Aboriginal Relics. These should be recorded and removed if considered practical.

While the history of seismic disturbances in the area is limited to quite minor events, seismic activity in the inundated area should be monitored for several years before and after the Dam is built and the Dam should be designed to be structurally safe if seismic activity occurs.

An intensive investigation already in hand of the water quality in the streams upstream of the Dam will continue for several years after the Dam is completed. The maintenance of a high water quality in the Dam is necessary. The Town Plan of Esk Shire provides for possible controls on subdivision, land use, etc. in an area around the inundated area. A 'Catchment Area' provided for in the Irrigation Act 1922-1977 and the Water Act 1926-1976 has already been declared and this provides also for measures to control water quality. The monitoring of water quality should continue and rural and recreation activities and non-rural development should be conducted in a manner that will maintain water quality.

Split-Yard Creek Dam will be built in an area already partly cleared for grazing. The inundated area will be completely cleared of timber, but this should not materially affect fauna since extensive areas of similar cleared land occur in the vicinity and the inundated area is small. Because of the rapid fluctuations in water level in the pumping and generating cycles, Split-Yard Creek Dam will be unsuitable for recreation. It will not be visible from Wivenhoe Dam.

The construction of the powerhouse, channels and access road associated with the Pumped Storage project will affect a small patch of rainforest by reducing its area. No alternative site for the various installations is available. No other adverse impacts have been identified.

The owners of properties directly affected in whole or in part by the construction of Wivenhoe Dam, the Pumped Storage Hydro-electric Project and associated relocated roads and services are entitled to compensation. The owners of some properties not directly affected by the works will have to bear some social and economic costs as a result of the construction of the projects. Some businesses in Esk and Toogoolawah will lose income as a result of the loss of rural production from the inundated area.

Current urban water management and pricing policies are unlikely to be effective in reducing the wasteful use of water. New management and pricing policies will have to be examined in the future with a view to making the best use of the scarce surface water resources available in the Region. Consideration should also be given as to whether the incremental cost method of cost allocation is the fairest way to allocate costs to purposes, or whether, for future multi-purpose dams, a method that examines the benefit the purpose receives from the project should not also be considered. Cost allocations on this basis might make some purposes unjustifiable.

SECTION 1

THE PROJECT

1.1 SYNOPSIS

This Section briefly introduces the project. Details of the project are contained in later Sections and Appendices.

1.2 INTRODUCTION

In November 1971 the Queensland Government approved the recommendations of the Moreton Regional Water Advisory Committee on the future sources of water supply for the City of Brisbane and adjacent areas and for Toowoomba City. As a consequence of the approval of the recommendations the next source of water supply for the Brisbane Conurbation was to be a dam on the Brisbane River at Wivenhoe. This dam was to be built to provide as high a degree of flood mitigation as was economical in addition to its water supply function. In August 1972 the Co-ordinator-General was appointed interim Constructing Authority for the Wivenhoe Dam Project.

1.3 THE SITE AND STRUCTURE

The site of the proposed Wivenhoe Dam is at A.M.T.D. 150 kilometres on the Brisbane River, 65 kilometres by road from Brisbane and just upstream of the junction of Lockyer Creek and the Brisbane River. It is proposed to construct a water storage facility of about 2.5 million megalitres capacity, of which 1.14 million megalitres will be used as an urban water storage and 1.4 million megalitres as flood storage. The proposed Dam will command a 7 070 square kilometres catchment which includes the Stanley River and the upper and middle reaches of the Brisbane River. See Figure 1.

1.4 MULTI-PURPOSE NATURE OF PROPOSAL

The Dam was originally planned as a major augmentation of the water storages for urban water supply to Brisbane City and the Local Authorities contiguous to the City and as a major flood mitigation structure to reduce river flood heights in Brisbane and Ipswich Cities and Moreton Shire. The lake behind the Dam could also provide a major recreational resource for the Moreton Region provided its use for this purpose is compatible with the maintenance of water quality. Recently a decision has been made to use the Dam as the lower storage for a Pumped Hydro-electric Scheme. The Dam is also a possible source for boiler feed and cooling water for the next thermal power station located in South East Queensland, if the new station is not located on the coast.

When a dam is to be used for a number of purposes, care should be taken to ensure that the requirements for a

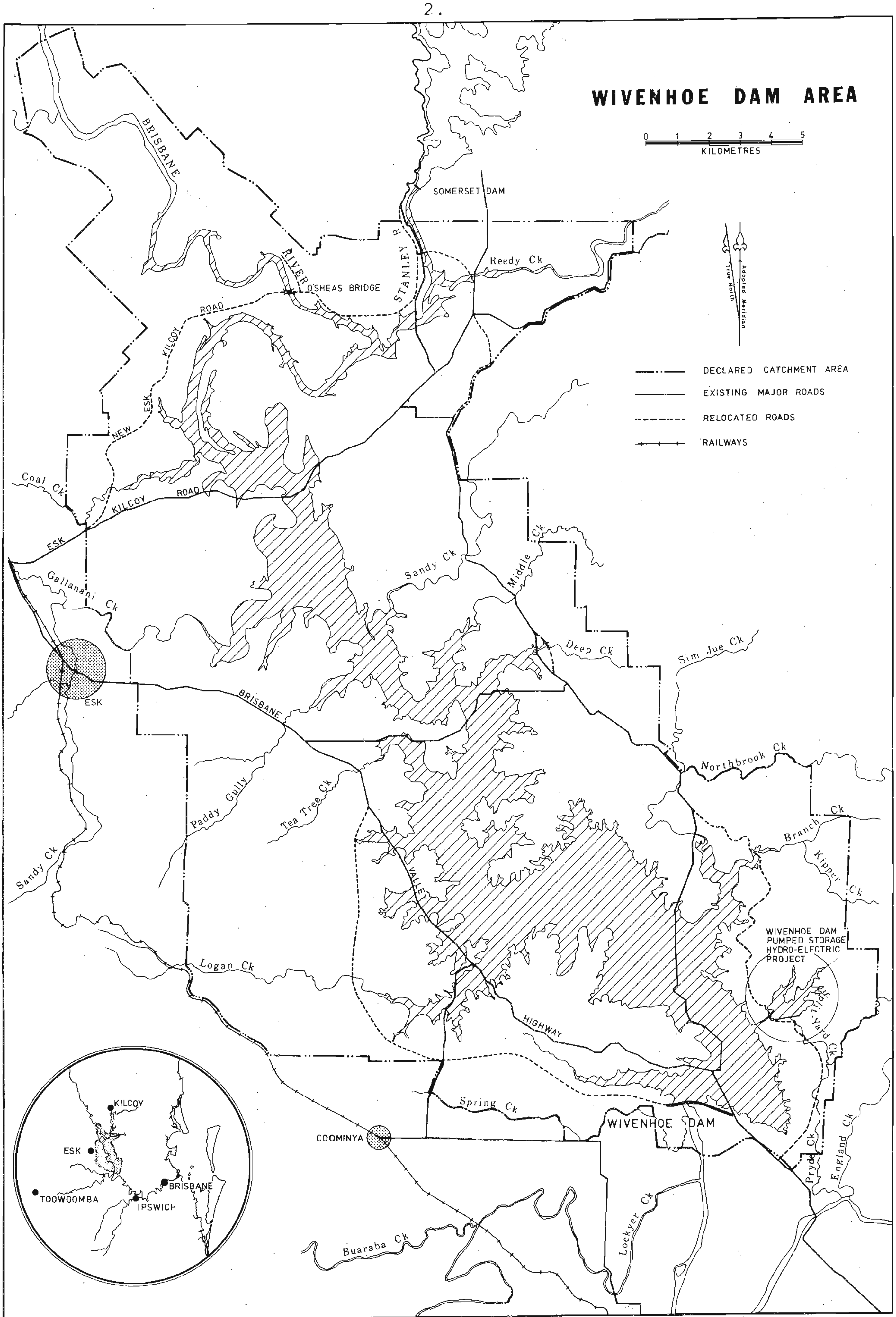

WIVENHOE DAM AREA
0 1 2 3 4 5
KILOMETRES
True North
Adopted Meridian
DECLARED CATCHMENT AREA
EXISTING MAJOR ROADS
RELOCATED ROADS
RAILWAYS
BRISBANE
RIVER
SOMERSET DAM
STANLEY R
O'SHEAS BRIDGE
Reedy Ck
KILCOY ROAD
NEW ESK
ESK KILCOY ROAD
Coal Ck
Gallanani Ck
Sandy Ck
Middle Ck
Deep Ck
Sim Jue Ck
ESK
BRISBANE
Northbrook Ck
Paddy Gully
Tea Tree Ck
Branch Ck
Kipper Ck
Sandy Ck
VALLEY
WIVENHOE DAM
PUMPED STORAGE
HYDRO-ELECTRIC
PROJECT
Logan Ck
Split Yard Ck
HIGHWAY
Spring Ck
WIVENHOE DAM
COOMINYA
Pryde Ck
England Ck
Lockyer Ck
Buaraba Ck
KILCOY
ESK
BRISBANE
TOOWOOMBA
IPSWICH

FIGURE 1

particular purpose do not conflict with the use of the facility for the other purposes. It is also necessary to identify the actions that should be taken both upstream and downstream of the Dam to ensure that the full benefit, due to each purpose, is attained, i.e. controls on certain types of land use to maintain water quality, flood plain zoning to control encroachment onto the flood plain etc.

1.5 MULTI-OBJECTIVE CONSIDERATIONS

Construction of the Wivenhoe Dam will result in the inundation of large areas of land upstream of the site. This will displace present land use in the area and this will have an effect on the social and economic activity in the area as well as an effect on the environment. The Dam will provide a major augmentation to the Brisbane Conurbation's water supply and it will have a major flood mitigation effect in urban areas downstream. The Dam will therefore have major social as well as economic effects in the lower reaches of the Brisbane River. The impact of the Dam should be assessed in terms of its contribution, whether negative or positive, towards the objectives of -

(a) economic efficiency;

(b) regional development;

(c) social well-being; and

(d) environmental quality.

When examining the effects of the various purposes for which the Dam will be used, measures should be proposed to 'minimise' the detrimental effects and 'maximise' the favourable effects and these measures should influence the final design of the project. The final proposal should be one of net benefit to the community with the beneficiaries and cost bearers clearly identified.

The proposal should not be viewed simply as an engineering work. Any associated management strategies, determined as necessary to ensure the maximum net benefit from any purpose, should be considered to form part of the proposal. If the management strategies are not implemented, the resultant effects of the impact of the Dam could be substantially different from those described.

SECTION 2

URBAN WATER SUPPLY IN THE MORETON REGION

2.1 SYNOPSIS

The urban water needs of the Moreton Region and existing and possible future water storages are described. The historical background and the investigations leading to the decision to construct a dam on the Brisbane River for urban water supply and flood mitigation are discussed. Details of the proposed dam are presented.

2.2 REGIONAL WATER NEEDS

2.2.1 Defining the Region

The Moreton Region occupies the extreme south east corner of the State of Queensland and comprises an area of approximately 22 000 square kilometres. It includes the Cities of Brisbane, Gold Coast, Ipswich and Redcliffe, and thirteen Shires. Local Authority boundaries are not always coincident with watersheds so that various catchments affecting the water resources within the Region extend beyond the boundaries of the Region.

About 57% of the State's population live in the Region which comprises about 1¼ per cent of the area of the State. The 1976 Census figures showed that the average population density within the Region is 55 persons per square kilometre and that Brisbane City contains about 60 per cent of the population of the Region. The regional population is expected to increase in the thirty years from 1971 to 2001 from about 1 million to about 1.8 million.

2.2.2 Urban Water Demand - Current

During the ten year period 1960/61 to 1970/71 average urban water consumption throughout the Region increased from 264 megalitres per day to 519 megalitres per day. In the same period, the population served by water supply reticulation increased from 672 000 to 993 000 and the per capita average daily consumption increased from 393 to 524 litres per day.

2.2.3 Urban Water Supply - Current

The total capacity of urban water storages now constructed is greater than 809 700 megalitres, with a yield of about 1 055 megalitres per day (at an assessed risk of depletion of 1 per cent).[1]

1. A one per cent risk of depletion means that, on average, during one year in each 100 years, either total or partial failure of the system's ability to supply the stated yield would occur, for an unspecified part of the year. In actual fact, complete depletion would normally be avoided by rationing.

This total yield includes water fully committed to irrigation use from Atkinson Dam (34 megalitres approx. per day), Moogerah Dam (34 megalitres approx. per day) and Maroon Dam (32 megalitres approx. per day). About 18 megalitres per day from Perseverance Dam is diverted out of the region to provide water for Toowoomba City.

2.2.4 Future Urban Water Demand

In addition to the growth in demand resulting from population increases, per capita demands are also increasing and will no doubt continue to increase in line with trends experienced elsewhere throughout the world. Gipps (1) has suggested that total urban water consumption in the year 2001 could be at least two and one-half times that of 1971, i.e. consumption by 2001 could approach 1 300 megalitres per day. Cossins (2) considers that by the year 2001 the average per capita consumption will have risen to over 1 000 litres per day, implying that total consumption could approach 2 000 megalitres per day. Cossins (2) provides data for the Brisbane Conurbation that would indicate that the total assessed yield from storages supplying the Conurbation, given current institutional arrangements, is 650 megalitres per day (at 1 per cent risk of depletion). Cossins (2) by projecting demands on the system, shows that, in any one year, the risk of depletion of the supplies from present headworks increases from 1½ per cent in 1978 to 3 per cent in 1979 to 8 per cent in 1980 and to 20 per cent in 1981. It is not possible to extrapolate the results beyond this point, but Cossins' analysis suggests that the risk of depletion, i.e. the risk that water has to be severely rationed to make the supply last through a major drought, increases eightfold if the commissioning of a new storage is delayed from 1975 to 1980, and twentyfold if the commissioning is delayed to 1981. The analysis also shows that, although there is an abnormal increase in demand during drought periods, this increase is only equal to the normal growth in demand over two years. The normal annual growth of demand is so great that, in the event of a long drought, severe restrictions would have to be imposed.

While the increasing risk of depletion of the present sources of supply makes the provision of an additional storage necessary, other means of managing the demand for water should be examined for the future. Such means include network interconnections, demand management through pricing policies etc. These management policies would require a change in public attitudes and they are not available in the short term.

2.2.5 Other Regional Needs

Present trends indicate that the limiting factor in the development of the Moreton Region will be the amount of water which can be obtained from natural sources unless, in the future, other possible sources such as desalination, effluent reuse etc., become economically feasible. Consequently a decision concerning the use of the water resources in the Region should not prematurely commit those resources to a particular purpose, such as urban water supply, or to meet a particular objective. The multiple purposes for which the water resources of the Region could be used and the multiple objectives which could be satisfied through their use should be taken into account. These considerations are important for the Moreton Region because the Region's population not only has a need for potable water, but also for recreation, power, flood mitigation etc. The construction of any additional storage in the Region should be directed to meeting, as far as is feasible, as many of these needs as possible.

The incidence of flooding in Brisbane has been much less this century than in the latter half of the last century. This is mostly due to the lower and less intense rainfalls experienced this century than previously and partly to the construction of certain flood mitigation works on the Brisbane River system some thirty years ago. It would be unrealistic, however, to assume that the seventy years of immunity from floods as large as that of January 1974 has been other than fortuitous. Four larger floods and two of comparable magnitude occurred in the last 60 years of the last century. Also some areas of the flood plains of creeks that are tributary to the Brisbane River or the Bremer River, in Brisbane and Ipswich Cities and Moreton Shire, may be flooded either by backwater from the river or by local creek flooding. The Bremer River flood plain in Ipswich City is also subject to flooding from the Bremer River and by backwater from the Brisbane River.

The development of a large thermal power station in Central Queensland, which will transmit energy to load centres in South East Queensland, makes it important that some means should be found to generate power to meet peak loads. One solution which has been adopted in other States and other countries has been the construction of pumped storage hydro-electric power schemes. Such schemes require two water storages closely spaced but at considerably different elevations. Construction of a water storage dam such as the proposed dam at Wivenhoe provides an opportunity, by the addition of a second high level storage, for the development of a major pumped storage scheme for inclusion in the electricity distribution network. A major thermal power station located in or near the Region is likely in the future. Modern thermal power stations require large quantities of water and the Moreton Region could be required to provide about 32 000 megalitres of water per year for such use if the future power station is not located on the coast so as to use sea water for cooling purposes.

The greatest recreational activity in southern Queensland, both for day trips and holidays, is associated with oceanfront land and beaches. Population growth is, however, placing greater demands on seafront areas and in a number of cases the ecosystems involved are deteriorating. Prior to the construction of large water supply storages there were negligible inland areas of fresh water which could be used for recreation in the Region. However, when after World War II the Somerset Dam reservoir became available for certain recreational activities, it was eagerly exploited. Subsequently, the provision of recreational facilities at a number of water storages which have been constructed in the Moreton Region since World War II has resulted in a high level of use of the facilities provided. In 1974/75 an estimated 100 000 to 130 000 persons visited Moogerah Dam and between 60 000 and 85 000 people visited Maroon Dam. (3) It is evident that dam waterfront areas and environs provide an alternative for seafront recreation for at least portion of the population. From a regional point of view, the anticipated increase in recreational requirement per capita and the increase in population, combined with the fragility of many coastline areas, will create a need for substitute/additional recreational facilities throughout the Region. The apparent preference of Australians for water-based activity suggests that the potential of the foreshore areas of major storages for recreation should be considered.

2.3 INVENTORY OF REGIONAL WATER RESOURCES

2.3.1 Rainfall

Average annual rainfall for the Moreton Region varies from more than 2 000 mm on heights near the coast to less than 700 mm in some areas adjacent to its western boundary. Average mean annual rainfall over the Region as a whole is about 960 mm. There are wide fluctuations between wet and dry years and sequences of years having below or above average rainfall occur. The rainfall is not evenly distributed throughout the year - there is a summer 'wet season' followed by a much drier winter.

2.3.2 Stream Flow

The Brisbane River system is the dominant river basin and occupies two-thirds of the total regional area. The river carries about 40 per cent of the total regional runoff. The Logan-Albert system is another relatively large catchment in the Region. Apart from these systems the rivers in the Region, in general, are short and steep in their upper reaches before emerging into flat coastal plains.

Beattie (3) estimated mean annual runoff from various sub-catchments within the Region as set out in Table 2.1 below. Only a small proportion of the runoff from the flat coastal areas is capable of economic use because of the lack of suitable dam sites and/or other constraints. This reduces to 1 700 000 megalitres the mean annual runoff from areas where regulation and control are possible. The degree of regulation practicable reduces the harvestable yield to a considerably lower figure.

TABLE 2.1

ESTIMATED ANNUAL RUN-OFF FROM SUB-CATCHMENTS WITHIN REGION

Catchment	Approx. Area (km^2)	Estimated Mean Annual Runoff to the Ocean (megalitres)
Streams between N.S.W. border and the Brisbane River catchment	5 100	1 500 000
Brisbane River catchment	13 500	1 300 000
Streams north of Brisbane up to and including the Maroochy River	1 700	400 000
TOTALS	20 300	3 200 000

Source: Beattie, D.W. (3)

2.3.3 Groundwater

The major sources of groundwater in the Region are located in alluvial deposits along the major river systems and in the larger off-shore sand islands. Estimated yields that might be available from the major alluvial sources are set out in Table 2.2. The figures lack any high degree of precision and no depletion risks have been determined for the yield estimates.

TABLE 2.2

ESTIMATED GROUNDWATER YIELD FROM MAJOR ALLUVIAL DEPOSITS

Area	Estimated Annual Yield (megalitres)	Estimated Daily Yield (megalitres)
Brisbane Valley (to Fernvale)	14 800	40.6
Lockyer Valley	66 600	182.2
Bremer Valley	2 200	6.0
Fassifern Valley	12 300	33.8
Logan and Albert Valleys	25 900	71.0
Stanley Valley	6 700	18.4
TOTALS	128 500	352.0

Source: Gipps, R.deV. (1).

It has been established that there are potential reserves of groundwater in the sand mass of North Stradbroke Island and, by analogy, Moreton Island may perhaps contain a similar volume. Harvesting and transport costs would be very high. A possible yield of 182 megalitres per day has been estimated for North Stradbroke Island.

2.3.4 Existing Storages and Yield

Fourteen dams and several weirs have been built to date on various streams throughout the Region. The major developments have taken place on the Brisbane, North Pine and Nerang Rivers.

Table 2.3 lists the dams already constructed, their storage capacity, estimated daily yield and present use of each storage. The total capacity of storages now constructed exceeds 809 700 megalitres and the estimated yield is 1 055 megalitres per day.

In addition to the major storages listed in Table 2.3 several weirs (including seven in the Brisbane River system) with a total capacity of 2 020 megalitres have been constructed.

TABLE 2.3

WATER STORAGES - MORETON REGION

Storage	Stream	* Capacity at F.S.L. Ml	Estimated Yield Ml/day	Present Use
Brisbane River System				
Somerset Dam	Stanley River	370 000	511	Urban water supply
Lake Moogerah	Reynold's Ck.	92 600	68	Irrigation, Urban and Industrial water supply
Atkinson Lagoon	Off Buaraba Ck.	31 300	34	Irrigation
Lake Manchester	Cabbage Tree Ck.	25 900	21	Urban water supply
Perseverance Ck. Dam	Perseverance Ck.		18	Toowoomba City water supply
Other River Systems				
Advancetown Dam (Stage I)	Nerang River	41 800	92	Urban water supply
North Pine River Dam	North Pine River	202 000	155	Urban water supply
Little Nerang Dam	Little Nerang Ck.	3 600	37	Urban water supply
Maroon Dam	Burnett Ck.	42 500	32	Irrigation
Leslie Harrison Dam	Tingalpa Ck.		21	Urban water supply
Lake Kurwongbah	Sideling Ck.		16	Urban water supply
Tallebudgera Ck. Dam	Tallebudgera Ck.		15	Urban water supply
Wappa Ck. Dam	Wappa Ck.		12	Urban water supply
Enoggera/Gold Ck. Reservoirs	Enoggera and Gold Cks.		12	Urban water supply
Adlington Ck. Dam	Adlington Ck.		11*	Urban water supply
		>809 700	1 055	
Committed or Under Construction				
Cooloolabin	Wappa Ck.		33*	Urban water supply
Advancetown Dam (Stage II)	Nerang River	229 000	161	Urban water supply
Wivenhoe Dam	Brisbane River	1 140 000	488	Urban water supply
Cressbrook Ck. Dam	Cressbrook Ck.		14*	Toowoomba City water supply
			696	

Source: Gipps, R.deV. (1). * Additional to listing in source tabulation.

2.3.5 Other Storages

A number of additional storage sites are known to be available within the Region. Details of estimated daily yields from each of these sites are set out in Table 2.4.

TABLE 2.4

POSSIBLE FUTURE STORAGES AND ESTIMATED DAILY YIELD

Storage Site	Location	Estimated Daily Yield (megalitres)
Wolffdene	Albert River	309
Cedar Grove	Logan River	227
Tallebudgera	Tallebudgera Creek	72
South Pine	South Pine River	59
Currumbin	Currumbin Creek	43
Coomera	Coomera River	35
Mudgeeraba	Mudgeeraba Creek	23
		768

Source: Gipps, R.deV. (1).

The storages as listed, if developed, would increase the estimated daily yield from the Region as a whole to some 2 519 megalitres per day. No account has been taken of the possible yield from that part of the Mary River within the Region.

2.3.6 Present and Potential Storage - Summary

From all sources the total available supply within the Region including resources at present in use for or committed to irrigation purposes may be summarised as follows:

Existing Storages	1 055	megalitres	per	day
Committed Storages	696	"	"	"
Possible Future Storages	768	"	"	"
Groundwater Sources	352	"	"	"
North Stradbroke Island	182	"	"	"
TOTAL	3 053	"	"	"

It should be noted that the estimated daily demand for urban water supply in 2001, discussed earlier, could be between 1 300 and 2 000 megalitres per day. If current irrigation (rural) usage is included, the total demand could be between 2 020 and 2 700 megalitres per day. As the water supply potential within the Region is limited, demand management, recycling, reuse, desalination, system interconnection etc., will become very important after the year 2001.

2.4 ABILITY TO MEET DEMANDS

2.4.1 Current Management Structure

At present, the responsibility for the provision of water supplies is shared among several State Departments and Local Authorities as follows:

The Irrigation and Water Supply Commission is responsible under the Irrigation Act 1922-1977 and the Water Act 1926-1976 for

(a) the investigation and recording of the State's water resources and planning for their conservation and efficient utilisation;

(b) the licensing and control of the use of those water resources;

(c) the investigation, design, construction and operation of major water conservation projects and irrigation works; and

(d) the constitution and supervision of Areas and Boards for Water Supply.

Recently the State Government has decided that the Commission should also take over the responsibility for the planning, design and construction of major dams for urban water supply.

The Department of Local Government is responsible for administering the Local Government Act 1936-1977 in addition to other legislation including the Sewerage and Water Supply Act 1949-1974. Where expenditure of public funds for town water supply schemes is involved, the Department has certain responsibilities. The Department may act as consultant to Local Authorities in carrying out feasibility studies or the planning, design and supervision of construction of water supply schemes except as provided above for the major dam component of any schemes.

Local Authorities are responsible for the provision of town water supplies. Section 32(14) of the Local Government Act 1936-1977 gives Local Authorities the right to build dams and other works in their own Local Authority area. Where water conservation works and diversion of water from streams are concerned, the annual and daily quantities of water to which a Local Authority is entitled are determined by the Commissioner of Irrigation and Water Supply, and the entire proposal must be approved by the Governor in Council.

The City of Brisbane controls a number of dams and weirs under a variety of legislation. The storages controlled by the city are Somerset Dam, Lake Manchester, Mount Crosby Weir, Enoggera Reservoir, Gold Creek Reservoir and North Pine River Dam.

The number of authorities involved in water resource management in itself represents a potential management problem, especially where an Authority, in order to supply water to its area, needs to build dams, etc. in the area of another Local Authority. Consideration has been given to the establishment of a Bulk Water Supply Authority which would be responsible for policy, planning and administration of bulk urban water supply within the Region. The Government decided early in 1977 not to proceed with the establishment of such an Authority.

2.4.2 Some Current Management Problems

In addition to the demand-supply problem in respect of urban water already discussed, other current problems include:

- urban development in water supply catchment areas (for both current and potential storages), which creates a need for controls over land use in catchments.

- the competition for water. At the present time this is minimal although it will become an important issue as urban demands increase both absolutely and relatively to rural demands in the Region. A prohibition has already been placed on the expansion of irrigation, using water drawn from the Brisbane River above Mt. Crosby, and the tributaries above Wivenhoe Dam site.

  Urban areas requiring water are not necessarily adjacent to sources of supply. Somerset, North Pine River and Advancetown Dams are all situated outside the Local Authority areas where most of the water drawn from them is used. Similarly, the Wivenhoe Dam site in Esk Shire is situated well outside the Brisbane Conurbation. As total demand increases in the Region, the transportation of water will become increasingly important and necessary.

The transfer of processed water from one Local Authority to another is already common and is a potential source of conflict. Some of the current transfers include -

- from Redcliffe City to Caboolture Shire at Deception Bay
- from Pine Rivers Shire to Redcliffe City
- from Gold Coast City to Albert Shire
- from Ipswich City to Moreton Shire
- from Brisbane City to Redcliffe City, Ipswich City, Albert Shire, Beaudesert Shire, Moreton Shire and Pine Rivers Shire

- flood hazard and flood plain development. Water supply storage and flood mitigation storage will always be in competition for the available storage capacity on the Brisbane River. However, non-structural measures to reduce flood loss as well as structural measures will be required if the full benefit of flood storages is to be achieved. The fragmentation of responsibilities makes it difficult at present to implement flood plain management measures such as land use controls to ensure that the flood mitigation effects of flood storages are not lost over time by further development of the flood plain.

- recreational demands. Water-orientated recreational needs of the Region's population can partly be met by the use of storages in the Region. The potential conflict, however, between these demands and water quality demands is another management problem.

2.4.3 Ability of Management to Meet Problems

It is doubtful whether the current management structure could, in the future, satisfactorily cope with the diverse needs for water in the Region. The management of the water resource should ensure the maintenance of adequate supplies and water quality, and yet provide for recreational needs, protect the environment, control development patterns, provide flood mitigation, etc. At some time in the future some statutory machinery will be needed to provide a mechanism for rationalising water resource use and management in the Region.

2.4.4 Resource Limitations

While some local supply problems could occur this century, some time early next century, provided the Regional population continues to grow and after all the possible dam sites listed earlier are developed, severe supply problems of a Regional scale will occur. Measures to reduce demand will be necessary or else alternative supply sources will have to be developed.

Alternative supply sources in the future might include:

- diversion of water into the Region from catchments outside the Region; for example, from the Mary River only partly in the Region.
- limited supply possibilities offered by the off-shore sand islands of North Stradbroke and Moreton. (These are not attractive in the short term because of high construction and operation and maintenance costs.)
- desalination methods for converting salt water (currently excluded for cost reasons).
- reuse of treated sewage effluent. (A pilot study along these lines has recently been completed by the Queensland Department of Local Government. In the present state of knowledge, the water would be too costly to distribute and to treat to make it acceptable to industrial users. Only about 30 per cent of all water delivered from water treatment works is available for reuse.)
- reduction of system losses by increased maintenance programmes. Currently some 25 per cent of treated water in Brisbane, it is estimated, is lost through leakages.

Measures to reduce demand that are directed to encouraging more efficient water usage will be as essential in the future as the provision of further supply sources. Efficient use could be encouraged through appropriate regulatory and pricing policies. Such policies could include -

- recycling
- metering of domestic consumption
- a pricing structure which would discourage wasteful overuse

Also the acceptance of a higher degree of risk of depletion for completed storages and the increased probability of rationing in any one year would increase system yield.

The forecast demand-supply problem fairly early next century could be delayed with appropriate policies. The choice of an appropriate policy and/or mix of policies will ultimately be dictated by political and financial considerations. The community should not be led to expect that water will be available for consumption at an increasing annual per capita rate.

The change needed in community attitudes to ensure a less wasteful use of water will take a long time to come about and in the short term the only alternative is the construction of another storage.

2.5 BACKGROUND TO THE DECISION TO CONSTRUCT WIVENHOE DAM

2.5.1 Historical Background

In the earlier years of settlement it was possible to obtain water for the developing town of Brisbane from nearby sources of small capacity, but by 1885 it was recognised that a safe supply could only be obtained by exploiting one of the major streams, and the Brisbane River was the obvious choice. A small weir and pumping station were subsequently established at Mt. Crosby, above the limit of salt water, from where water was piped to Brisbane. The weir could provide only a short term balancing storage, and the 1902-3 drought revealed that the Brisbane water supply system, with no adequate long term storage, was extremely vulnerable.

An effort to obtain the necessary storage on a small tributary with a favourable site for a dam (Cabbage Tree Creek) proved unfortunate, largely because the local hydrological conditions were not understood, and the available runoff was over-estimated.

Water from underground sources, including the sand dune islands off Moreton Bay (particularly North Stradbroke Island), was considered but then, as at the present time, this water could not be obtained economically. The high flood risk to Brisbane focussed attention on the Brisbane River. A major dam at Middle Creek was proposed, but difficulties of finance and perhaps receding memories of the disaster of the 1893 flood led to abandonment of this proposal.

Surveys and investigational work continued on proposals to develop the Brisbane River but there were interests outside the Government which advocated other developments. These proposals evoked bitter controversies and led to the appointment of the Gutteridge Royal Commission in 1927 to enquire into water supply and flood mitigation for Brisbane. The Commissioner's Report in 1928 gave a comprehensive review of all sources, so far as data thereon were available, but unequivocally considered that supply should be drawn from the Brisbane River system. One outcome of the Royal Commission was the transfer of the water supply system to the Brisbane City Council.

Without any adequate long term storages the water supply system was unable to cope with drought conditions and Brisbane residents were frequently subjected to severe rationing. The risk of severe rationing, such as would have been required if another drought as bad as the 1902 drought occurred, remained until 1943, when Somerset Dam was first put into service. This dam provided the first effective addition to the storage since the dam on Cabbage Tree Creek (Lake Manchester) was built in 1916.

In retrospect this appears as a colossal, if involuntary, gamble on the part of the city in which, fortunately, it won. However, to avoid any such repetition in the future, the Government subsequently appointed a representative committee which was required to review trends and advise on future requirements well in advance of actual need so that the necessary planning could be carried out.

During its existence the Stanley River Works Board realised that the water supply demand had increased at a far greater rate than had been anticipated when the construction of Somerset Dam had first been approved, and that a further source of supply would be required much earlier than originally anticipated. The Board recommended that the next development to follow Somerset Dam should be a storage on the North Pine River and this recommendation was later approved and acted on by the Government and the Brisbane City Council.

Somerset Dam has proved successful in flood mitigation and it has provided a reliable water supply for the Brisbane Conurbation to this date. (It is reported that for the 1955 flood the flood damage savings were greater than the cost of flood mitigation expenditure on the dam. During the 1974 flood, it is estimated that the dam had the effect of reducing flood losses by $80 million.)

In 1958 the Stanley River Works Board was disbanded and its obligations with respect to the Brisbane area water supply were passed to the Brisbane Water Supply Planning Committee. This Committee carried on with the same policies and lines of investigation as the Board with regard to forward planning of the Conurbation's water supply.

The Engineering staff of the Board were transferred to the Co-ordinator-General's Department and became the Hydraulics Branch of that Department. This Branch carried on the investigations with respect to Brisbane's water supply started by the Stanley River Works Board. The Committee could also draw on the Water Supply Branches of the Local Government Department and the Brisbane City Council and on the Irrigation and Water Supply Commission for technical assistance.

When the Committee was set up, a policy covering future requirements for at least ten years had been approved, but the Committee's general terms of reference covered the period to at least the year 2000. So as to avoid any slowing down in the work, in about 1964 the Committee made recommendations to the Co-ordinator-General and the Brisbane City Council outlining specific investigations and giving suggestions as to who should be responsible for carrying them out. These were approved by the Government and the Brisbane City Council.

2.5.2 Towards a Policy for Water Resource Development in the Moreton Region

Both the Stanley River Works Board and the Water Supply Planning Committee recognised the need for unified control of the resources in water and both foresaw that, within the foreseeable future, without adequate controls, there could be fierce competition between groups of users. The Government, however, was not prepared to accept recommendations for a Board or an Authority.

In January 1967, to clarify its own position and to provide a firm basis for further work, a series of recommendations was made by the Committee to the Government. All but two of these recommednations were approved and the two recommendations not approved did not affect the proposals to be investigated.

2.5.3 Resource Appraisal

Planning for the development of the North Pine River as an augmentation for the Brisbane Conurbation's water supply began in 1956. This was the first dam built for the Brisbane water supply outside the Brisbane River system. The North Pine Dam could meet the growing demand for only a limited number of years, and the Committee's activities were directed to establishing what development would be most satisfactory thereafter for the augmentation of water supply storages to meet the growing demand.

The Committee's investigations showed that the choice for the next storage was between the Brisbane and Albert Rivers as no other potential source could compete economically with a dam on either of these rivers. The results of the investigation were covered by three comprehensive reports.

The Co-ordinator-General's Department (4) investigated a proposed dam on the Brisbane River at two alternative sites and issued a report in 1971 which covered that investigation and the two investigations mentioned below.

The Department of Local Government (5) investigated a proposed dam on the Albert River at Wolffdene and issued a report in September 1970.

The Brisbane City Council's Department of Water Supply and Sewerage (6) reported on the Augmentation of the Water Supply to the Brisbane Conurbation. This report dealt with the trunk mains and treatment works which would be required if a dam was built on the Albert River or the Brisbane River and it compared the economics of water supply from each source. The conclusion was that urban water could be obtained at approximately the same cost from either scheme, although greater quantities could be obtained from the Brisbane system.

2.5.4 Co-ordinator-General's Department '1971 Report' (4)

The exploitation of the water resources of a river system can theoretically be done in two ways - by building a number of relatively small regulating storages to control those individual tributaries where physical conditions are suitable for dam development, or by building one or more large dams in the middle or lower valley. It is seldom that a series of upper tributary dams can be economically justified for the major development of the resources of a river.

The possible future dams on the Brisbane River for the Brisbane City water supply had to be evaluated, taking into account existing dams used to supply water to Brisbane and Toowoomba and a possible future dam for Toowoomba's water supply. The existing dams are Somerset Dam on the Stanley River and the minor Perseverance Creek Dam. The potential dams included those at sites on Cressbrook Creek, on Cooyar Creek, on the Upper Brisbane River near Linville and on the middle reaches of the Brisbane River at Wivenhoe and Middle Creek. (The dams at Middle Creek and Wivenhoe are mutually exclusive.)

Some of the findings and recommendations of this '1971 Report' were:

(1) A middle valley dam would provide water much more cheaply and also in greater quantity than would tributary dams in the Brisbane River system.

(2) A dam at Wolffdene on the Albert River would be cheaper in first cost but it would have a lesser yield. Unless there were serious diversions of water to other areas or uses, the ultimate cost of water would be approximately the same from either scheme, but might slightly favour a dam at Wivenhoe.

(3) That the next development of headworks for the Brisbane water supply be a multi-purpose dam in the Brisbane system, which will serve for both water supply and flood mitigation, the latter being included since the benefit cost ratio from expenditure necessary to extend a dam to provide flood mitigation beyond that required for a water supply storage only, is very high, and since there is still a very serious flood risk in Brisbane, Ipswich and the lower valley generally.

(4) That the location of such a dam be at the Wivenhoe site and that it be built to serve water supply and flood mitigation. To this end, it would have a gate controlled spillway and provide for an adequate flood compartment with control by gates of the order of thirty-eight (38) feet in height with their sill (fixed spillway crest) some twenty (20) feet below full supply level (F.S.L.) for water supply, these values being subject to review and reassessment in the design stage.

(5) That the full supply level be provisionally adopted at not less than R.L.215, and that consideration be given to a higher level of perhaps R.L.220, the economics of the higher level, and its effect on the operation of Somerset Dam.

The proposal for supply from the Brisbane system had an additional advantage in that it could be extended for flood mitigation at a relatively small cost. The reports and recommendation were submitted to the Moreton Regional Water Supply Advisory Committee which had been set up by the Government and this Committee's recommendations in favour of a dam, to be built on the Brisbane River, and planned for both water supply and flood mitigation, were accepted by the Government. The higher full supply level equivalent to EL 67 AHD providing a capacity of about 1 140 000 megalitres was approved. The Co-ordinator-General was nominated as the Constructing Authority pending a decision on the establishment of a Bulk Water Authority.

2.6 PROPOSED DAM

2.6.1 State of Design of Proposal

Concurrent with the process of selection of the Wivenhoe Dam proposal, a detailed investigation of the available site options was undertaken by the Co-ordinator-General's Department. (4). Foundation drilling was carried out at alternative adjacent sites, geological examinations and appraisals were obtained, and limited trial designs were undertaken to assess both the most economical type of structure and the project costs. The various values obtained for yield, storage volume, probable maximum flood, etc., would be reviewed in the final design and therefore modifications would be inevitable. Inflation and increased interest rates have greatly affected cost estimates since 1971.

In 1975 the Irrigation and Water Supply Commission, as the delegate of the Co-ordinator-General, was charged with the design and construction of the Dam. At this date the Commission has completed preliminary designs and is engaged on the final design of the Dam.

2.6.2 Relationship to Other Storages

Brisbane for more than thirty years has relied on Somerset Dam as its principal source of water supply. This dam is multi-purpose in that it is capable of mitigating floods in Brisbane and Ipswich as well as being used for water supply. The original flood compartment was reduced some years ago to provide greater water supply capacity, and the position now is that, of a total capacity of 884 000 megalitres, 370 000 megalitres (43 per cent) is devoted to water supply and 514 000 megalitres (57 per cent) is allocated to flood mitigation purposes, and held empty except in times of high valley runoff.

At Wivenhoe, if a dam was built as high as the land acquisition policy would allow with full supply level EL 67 AHD, it would provide about 1.14 million megalitres for water supply and about 1.4 million megalitres for flood storage.

Water in Wivenhoe Dam at F.S.L. EL 67 AHD will back up over the dissipator floor at Somerset Dam to a depth of approximately 6 metres. In maximum flood conditions, water depth at the dissipator at Somerset Dam will increase appreciably and the actual height reached during a flood will depend on the rate of water release from Somerset Dam. The safety of Somerset Dam under these conditions was checked during the investigations leading to the '1971 Report' and it was found to be safe. It has been rechecked since that date assuming a larger maximum flood and again found to be safe.

2.6.3 Operating Conditions

Under present operating conditions, water is released from Somerset Dam and it flows down the Stanley and Brisbane Rivers to be drawn off at Mt. Crosby for treatment and conveyance by trunk mains to Brisbane and elsewhere. The release from Somerset Dam is such that, together with the unregulated Brisbane River flow, and allowing for losses and abstractions en route, the required amount is available at the draw-off point. The value of Wivenhoe Dam is thus primarily the increased volume available from the regulation of the previously unregulated Brisbane River flow. The only useful way of assessing the yield of Wivenhoe is to state it as the additional yield available from the system due to the presence of the new Dam. Table 2.5, drawn from data in the '1971 Report', shows the relative volume of water available for depletion risks of one, two and three per cent. Wivenhoe Dam will increase the system capacity by about 80 per cent. (The figures for yield in Table 10.5 in Section 10 are the result of a more recent analysis undertaken during the design of the Dam.)

TABLE 2.5

AVERAGE DAILY YIELD - SOMERSET AND WIVENHOE DAMS

For F.S.L. Wivenhoe Dam EL 67 AHD (Megalitres/day)

Risk of Depletion	Somerset Dam & Brisbane River (Unregulated)	Somerset & Wivenhoe Dams	Additional Yield due to Wivenhoe Dam
1 per cent	580	1 056	476
2 per cent	637	1 122	485
3 per cent	680	1 165	485

Source: Gipps, R.deV. (7).

2.6.4 Possible Operating Procedures

(a) Water Supply

The Somerset and Wivenhoe Dams will be operated to maintain the water supply to the Brisbane Conurbation and possibly in the future, by pipe line, to the Lockyer towns. Operating procedures should aim to minimise evaporation losses, optimise water quality, and maximise yield.

(b) Flood Mitigation

The combined flood storage capacities of Somerset and Wivenhoe Dams will be available to mitigate flooding in the lower Brisbane flood plain and the operation of the two dams must be complementary so as to maximise flood mitigation. As the flood pondage in both dams is less than the total volume of a major flood, water must be discharged from Wivenhoe Dam during any major flood. The operation of the dams in flood times should aim to reduce the height of flood peaks downstream of Wivenhoe to the maximum extent practicable. To achieve this, account must be taken of the timing and volume of discharges from downstream tributaries. The catchment area commanded by Wivenhoe Dam will be 7 070 square kilometres, of which 1 330 square kilometres on the Stanley River are also commanded by Somerset Dam. The total catchment area of the Brisbane River system is 13 600 square kilometres.

2.6.5 Design Details

The site favours an embankment dam with a spillway towards the left abutment, out of the main river channel. The main rock type at the site is a rippable sandstone. The Dam will have a central clay core flanked by rolled sandstone from the spillway excavation at the left bank. The usual filters and blanket drain will be incorporated. The dissipator will most likely be a hydraulic jump type as developed by the United States Bureau of Reclamation. A deep inlet channel will provide water to outlets in the spillway retaining wall and it also will be capable of providing supplementary diversion capacity during floods which may occur in the later more critical stages of construction. A temporary diversion channel will be built on the right bank.

Core material is available within one kilometre of the embankment from the clays and sandy clays of the upper alluvial terrace. Gravel and sand for the filters and blanket drain are available from river deposits at four possible sites, all within seven kilometres of the dam site. Most of the filter material will have to be classified by screening with or without crushing of oversize. Concrete aggregates can be obtained from the same sources as the filter material and washing as well as classification to size will be required. There are several possible quarry sites for rip-rap, which may have to be carted some kilometres.

Details of the proposed dam are as follows:

Storage Capacity at F.S.L.	1 140 000 Ml
Flood Compartment	1 400 000 Ml
Full Supply Level	EL 67 AHD
Maximum Water Level	EL 77 AHD
Embankment Crest Level	EL 79 AHD

All of the water released from the dam will be discharged into the river downstream of the dam and it will then flow to the treatment works at Mt. Crosby. Provision is being made for the future conveyance of the raw water from the dam by pipeline to Mt. Crosby or elsewhere, if so determined, by the provision of a blanked off pipe outlet at the dam.

It would be possible to pass the daily water releases through a turbine and generate electricity and the economics of a hydro-electric set built into the dam have been examined. The most economical size would be a 30 MW set, but the return on the investment would be less than the present rate of interest on borrowed funds. Consequently it has been decided not to include a hydro-electric set in the dam. At a cost of about $300 000 it would be possible to provide for the installation of of a 30 MW set in the dam sometime in the future should conditions make such an installation favourable. Such provision will be made in the dam.

2.6.6 Construction Details

The Brisbane River at Wivenhoe Dam site is subject to flows ranging from a few cusecs to tens of thousands of cusecs. Flows of over 2 500 m^3/s are possible even in the winter season. A flow of 700 m^3/s is equalled or exceeded every year. The construction of the Dam is expected to be spread over four years, with the work in the river bed section being performed in the first two years, mainly in the dry seasons. The work in the river section will involve deep excavation in the core zone inside cofferdams which will be incorporated in the final structure.

During the construction of the Dam, so as to allow work to proceed in the river bed, the flow in the river will be passed through a temporary diversion channel built in the right bank. This diversion channel will pass the 1:5 probable frequency flood without overtopping the coffer dams. A 1:5 probable frequency flood means that there is one chance in five that a flood of that magnitude or greater will occur in any one year. Most of the material for the Dam embankment will be obtained from the excavation for the spillway and the spillway diversion channel and flood waters will be passed through this channel also. The most critical period will be during one wet season when the embankment will have been built to about EL 54 AHD. At that stage the combined diversion capacity of the two channels would be equivalent to about 1:1000 probable frequency flood. Finally the concrete monoliths in the spillway structure will be progressively raised so that at all times large floods can pass through the spillway channel. The 45 feet high sector gates will not be erected until the construction of the embankment is complete.

The risk and the degree of overtopping that can occur during the period of construction as a result of a major flood are considered in the construction requirements. These require certain stages and heights to be achieved during each 'dry' season. Reinforcement of the rockfill in those sections of the Dam that can be overtopped will be provided.

The construction schedule is such that a major failure of the partly completed Dam would be highly unlikely. Floods in the river during construction will be regulated and limited in size to some extent by the partially completed Dam. The precautions taken to protect the Dam against damage or failure due to a flood during the construction period should ensure that the urban areas downstream are not put to hazard by the construction of the Dam.

The timing of the Dam construction must also be co-ordinated with the construction of the Pumped Storage Hydro-electric Project.

SECTION 3

POWER (ELECTRICITY) GENERATION AND WIVENHOE DAM

3.1 SYNOPSIS

The possible use of the water released from the Dam to generate electricity is discussed. The use of the Dam as the lower storage for a proposed Pumped Storage Hydro-electric Project is described. It is possible that at some time in the future the Dam may be used to supply boiler feed and cooling water to a thermal power station.

3.2 GENERAL

The proposed Wivenhoe Dam was originally approved for construction for urban water supply and flood mitigation purposes. It has been recognised that the Dam has a potential for electricity generation if a hydro-electric power station was built in the Dam or if the Dam was used as the lower storage of a Pumped Storage Hydro-electric Project. The Electricity Supply Industry recognises that the Wivenhoe Dam is to be built for urban water supply and flood mitigation. However, the Pumped Storage Hydro-electric Scheme has been designed on the basis that the minimum operating level for the scheme of the water in Wivenhoe Dam will be EL 49 AHD and the industry would like to have influence in determining the operating rules for the Dam.

3.3 HYDRO-ELECTRIC GENERATION AT THE DAM

All the water to be used from the Dam for urban water supply for the Brisbane Conurbation will be released into the river downstream of the Dam where it will flow to the treatment works at Mt. Crosby. The water released from the Dam could be used to generate power by installing a hydro-electric station in the Dam. The planners in the electricity industry considered that a capacity of 30 MW was the minimum size that would be useful. The return on the investment required to install such a station in the Dam was calculated at about 6%. The interest rate on the loan funds which would be used to pay for the installation would exceed 10%, so a decision was made not to incorporate a hydro-electric station in the Dam. However it was agreed that the necessary pipe work etc. would be incorporated in the Dam so that a hydro-electric station could be incorporated in the Dam in future if it became economically feasible to do so.

3.4 WIVENHOE PUMPED STORAGE HYDRO-ELECTRIC POWER SCHEME

A decision has been made to build a pumped storage hydro-electric scheme with a generating capacity of 500 MW, using the Wivenhoe Dam as the lower storage.(8) The Pumped Storage site is on the east side of the Brisbane

River about 3 kilometres upstream from the Wivenhoe Bridge over the Brisbane River. The general level of the land at the Pumped Storage site rises abruptly from the river as a result of the Brisbane Valley fault. A small creek - Split-Yard Creek - drains this higher ground. It runs roughly parallel to the Brisbane River and within about one and one half kilometres of it. A dam across this creek will provide the upper pond.

The available mean head for generation is relatively low - about 91 metres - and there will be appreciable seasonal fluctuations in level in the lower storage, causing some problems in the design of the turbines. The variation in water level in the top storage during the cycle leads to major variations in the head and this is the major turbine and pump design problem. Investigations indicate that the economical scheme will comprise two units each of 250 MW capacity.

The lower pond is large and will have only minor fluctuations in level during daily cycles of pumping and generation. However, the water supply storage will be designed for depletion to about EL 40 AHD in the critical long duration droughts. It would never fall below EL 49 AHD except in severe drought situations. The Pumped Storage Scheme will not operate when the level of Wivenhoe Dam is below EL 49 AHD, as the associated civil engineering costs to permit of pumping from lower lake levels would be too high.

The upper pond will have a full supply level of about EL 166 AHD. The dam will be of earth and rock fill and will be about 70 metres high.

The working storage will be above EL 132 AHD, giving a maximum capacity of about 23 000 megalitres, which is roughly equivalent to ten hours operation of the turbines at full output. The normal daily cycle will use the volume above EL 154 AHD, making about 11 000 megalitres available to give about five hours operation at full output.

The design of the pumps and turbines allows for the amount of energy produced to vary, within limits, as heads different from the design head occur due to fluctuations in the water level in Wivenhoe Dam.

The power station will consist of two large individual concrete lined silos built side by side, each housing one unit. An open channel will be constructed between the lower storage and the powerhouse to ensure that the inlets to the pumps and the outlets for the turbines are covered with water at all times. Individual pressure tunnels will lead from the intake-outlet in the upper storage to each unit, branching to the pump outlets and turbine inlets.

Construction will take at least four years. About two-thirds of the purely civil engineering works will have to be completed before water is stored behind the Wivenhoe Dam. The construction of the scheme will need to start at about the same time as construction starts on Wivenhoe Dam. The construction timing of the silos in which the pumps and turbines will be placed must be closely co-ordinated with the construction of Wivenhoe Dam. Before energy can be generated by the scheme the water level in Wivenhoe Dam must be above EL 49 AHD.

3.5 FUTURE THERMAL POWER STATION

No decision has been made on the location of the next thermal power station to be built in South East Queensland. As the Brisbane City Conurbation would be the load centre for such a power station, it is likely to be located in the Moreton Region or close to it. It is estimated that such a power station would require 32 000 megalitres of water per year for boiler feed and cooling water if it was not located on the coast so as to use sea water for cooling purposes. If such a power station was not built on the coast, the necessary water would most likely be supplied from the Brisbane River system, probably from Wivenhoe Dam. It should be recognised that surface water sources available to the Region for drinking purposes are in short supply in the long term and should be preserved as far as possible for potable water supply. The possibility of a future power station and its effect has not been considered in this report.

SECTION 4

EXISTING ENVIRONMENT

4.1 SYNOPSIS

The existing natural and man-made environment in the catchment above the proposed Wivenhoe Dam is described. Only those elements of the environment which will be affected by the Dam are discussed in detail.

4.2 THE CATCHMENT - GEOGRAPHICAL LOCATION AND INFRASTRUCTURE

The 7 070 square kilometres catchment of the proposed Wivenhoe Dam includes the Stanley River and the upper and middle reaches of the Brisbane River. See Figure 1.

The Dam is located at A.M.T.D. 150 kilometres on the Brisbane River, 65 kilometres by road to the north west of Brisbane on the Brisbane Valley Highway. The total population in the catchment above the Dam site is less than 10 000 and it is well dispersed. The population has tended to decline, although the 1971 census indicated that it might now be static. The 1971 census shows that the largest town is Kilcoy with a population of 1 150, while Esk (700), Toogoolawah (730) and Woodford (900) are somewhat smaller. The 1976 census showed population increases in Esk and Kilcoy Shires due mostly to residential development outside the Dam catchment except for a small increase in population in the town of Kilcoy.

The small towns are well located so as to service the local pastoral, agricultural and forestry industries. The only notable secondary industries are a number of strategically located sawmills, a meatworks at Kilcoy, and a factory for the manufacture of dairy products at Woodford.

The area is reasonably well serviced with sealed roads. The Brisbane Valley branch railway terminates at Yarraman.

4.3 EXISTING LAND USE

The main types of land use within the catchment are:

- pastoral (beef production, based on grazing of both native and sown pastures). This is the dominant land use.
- dairying (bulk milk and cream)
- timber (significant, but confined mainly to State Timber Reserves)

- pastoral and timber (scattered areas on private land)
- agriculture (four prominent but relatively small areas)
- pastoral and agriculture (small areas in the Upper Stanley River catchment).

4.4 TERRAIN (PHYSIOGRAPHY)

The terrain can be divided into two main forms -

- highlands
- sub-coastal lowlands in the valley floor of the Stanley and Brisbane Rivers.

The ponded area and immediate surrounds of the proposed Dam are situated in the gently undulating, subdued topography of the Brisbane Valley. More rugged country occurs both east and west of Somerset Dam and to the north of the ponded area of the proposed Dam while two isolated groups of rocky hills formed by resistant rocks occur east of Esk and near Crossdale. East of the proposed ponded area the rugged D'Aguilar Range forms a discrete block of high country limiting the eastern edge of the valley. Much of the area which will be inundated consists of a series of alluvial terraces which extend for considerable distances from the present river channel.

4.5 GEOLOGY

The geology of the Moreton district, of which the Wivenhoe Dam catchment forms the northern part, has been described by V.G. Swindon (9). A further specific account has been prepared by Willmott W.F. and Siemon J.E. of the Geological Survey of Queensland, the full statement of which is attached as Appendix 1. The geology of the Brisbane Valley is shown on the Ipswich 1:250 000 Geological Sheet, and it is currently being remapped at 1:100 000 scale by the Geological Survey of Queensland.

4.6 MINERAL RESERVES

No mineral reserves are known in the submerged area. Mineral occurrences situated in the catchment area are described in Appendix 1. Minor amounts of arsenic, antimony and mercury are known to occur in the headwaters of streams in the catchment area. However, the water from the Brisbane River system has been used as the drinking water supply for the Brisbane Conurbation for many years and chemical testing of the water over many years has failed to show any significant concentration of these elements. The manganese content of the rocks in much of the catchment area could lead to manganese concentrations in the Dam and cause occasional trouble in the treatment process.

4.7 CONSTRUCTION MATERIALS

Considerable volumes of gravel and sand suitable for concrete aggregate are present in the existing river channel and in certain low alluvial terraces within the proposed ponded area. See Appendix 1.

Field observations and information from limited drilling suggest that the higher alluvial terraces are composed only of silts and clays.

The gravels are at present too remote from urban areas for economical exploitation, apart from the minor needs for road base and concrete aggregate of local communities such as Esk. However, future expansion of the Ipswich area, together with depletion of existing sources of river aggregate, may make exploitation of the Wivenhoe gravels economically feasible in the long-term future.

A small quarrying operation producing crushed quartzite, 'granite' and rhyolite for landscaping and ornamental purposes is active near Dundas.

4.8 GEOLOGICAL STRUCTURES

Immediately east of the proposed reservoir area, the rocks of the Toogoolawah Group are separated from the older rocks in the D'Aguilar Range by major fault structures forming the eastern edge of the Esk Trough. Although these faults are now largely inactive, minor earth tremors have been recorded with epicentres on the continuations of the fault further to the north. The strongest shock of magnitude m = 5 occurred near Kilcoy in 1913, while two weaker shocks of undetermined magnitude occurred near Murgon and Mt. Stanley (9 km east of Nanango) in 1955. Another shock, with a magnitude of m = 5.1, which occurred to the east near Mt. Nebo in 1960, was apparently unrelated to any recognised geological situation. See Appendix 1.

4.9 SPECIAL FEATURES OF INTEREST

No geological features of special scientific, scenic or aesthetic value are known in the area to be inundated. See Appendix 1.

4.10 SOILS

The Wivenhoe catchment forms the northern portion of the Moreton Region, the soils of which were mapped by Hubble, G.D. et al (10). Within the catchment, seven major and six minor soil types have been defined by the Department of Primary Industries.

4.11 VEGETATION

The vegetation in the catchment is primarily eucalypt open-forests of various kinds with closed-forests secondarily dominant and occurring on the more fertile soils. The effects of clearing and development are obvious in almost all communities.

The proposed Dam site and the land to be inundated by the storage have been extensively cleared for pastures and cultivation. One area of characteristic native river bank vegetation occurs just below the Somerset Dam. The Department of Primary Industries does not consider that this area of vegetation is unique and better examples are preserved in other areas of the Moreton Region.

4.12 SOIL EROSION

The soils of the catchment are all subject to varying types of erosion which affect the capability of the land for agricultural, pastoral or forestry purposes. They have been categorised on the basis of susceptibility to erosion and have been delineated by the Department of Primary Industries.

The land within the catchment is generally being used within its capability class for agricultural purposes. Considering the history of land development and the use and management of the area for the past 70 years, the existing erosion is mainly slight to minimal.

In the area which is being used for grazing, some 34 000 hectares, or 5 per cent of the total catchment, has suffered severe sheet and moderate rill erosion. Moderate sheet and rill erosion exists on about 22 per cent of the area which is being used mainly for grazing and cultivation purposes. Just over half of the area has suffered slight sheet and rill erosion. The erosion is negligible on about 19 per cent of the area. This area is mainly used for forestry or forestry combined with grazing in the upper catchment, and for grazing and cultivation in the lower parts of the catchment.

4.13 FAUNA

The area directly affected by the proposed Wivenhoe Dam was included within the "Moreton Region - Non-Urban Land Suitability Study" (11), and the fauna capability ratings for the habitats were assessed. The area affected by the Dam was rated as not very suitable for native fauna.

Some of the slopes and hills surrounding the storage were graded as of medium suitability for fauna. The fauna of these areas is not expected to suffer unduly if recreational use of the area and access to it are controlled.

The following species of native fishes are known to occur in the Brisbane River upstream of Wivenhoe Pocket: long-finned eel, carp, ceratodus, freshwater catfish, sea mullet, perch, an occasional Murray cod, and a number of the smaller fishes, e.g. gudgeon, etc. Of these, the long-finned eel and the sea mullet both require access to the sea. See Appendices 2 and 3.

4.14 ARCHAEOLOGICAL SITES - ABORIGINAL RELICS

An initial survey of the area likely to be affected by Wivenhoe Dam by the Department of Aboriginal and Islanders Advancement (12) indicated the existence of eight classifications of relics. The relics comprised twenty-two trees from which bark had been removed for the manufacture of canoes, containers, etc., three Bora rings or ceremonial grounds, one mythical site, one cave, four burial areas, four trees with axe cuts, three artefact finds, and one camp site.

Despite a long occupation by Europeans in the district and the resultant clearing of land, a large number of relics remain intact and most are good examples of the classifications they represent.

SECTION 5

AN ASSESSMENT OF THE IMPACT OF WIVENHOE DAM ON THE EXISTING ENVIRONMENT UPSTREAM OF THE DAM WALL

5.1 SYNOPSIS

The nature, magnitude and importance of the likely impacts on the environment, in the catchment area, due to the construction of the Dam at Wivenhoe are assessed. The impacts have been separated into four categories, namely, direct physical impact, indirect physical impact, economic and social impact within the catchment area.

Wivenhoe Dam will be a multi-purpose facility. It will be used for urban water supply, flood mitigation, recreation, and as the lower storage in a pumped storage hydro-electric scheme. The Dam will produce impacts which will affect land and its use upstream of the Dam. There will be a need to safeguard the performance of the Dam in terms of both water quality and storage capacity. It may be used in the future as the source of the water needed for a future major thermal power station located in the Region.

5.2 PHYSICAL IMPACT

5.2.1 Effect of the Water Body

A major water body placed in the central Brisbane River catchment will produce some changes in catchment hydrology, which will affect river regulation and flood behaviour. New deposition zones in the surface runoff system and some minor changes in the hydraulic gradient of underground waters will occur.

The immediate impact of the water body will be the loss of land suitable for irrigation between Barney's Rocks and Wivenhoe. Grazing areas will also be reduced by approximately 10 000 hectares.

A major beneficial effect of the water body will be the resultant change in landscape and scenery, i.e. in visual amenity. This will have a considerable effect on the desirability of the land for a range of purposes for which it would not previously have been considered. If the future lake is used for recreation of various types, a demand could grow for the use of the adjacent land for associated activities. This possible demand for the use of land for other than rural activities is likely to be the major land use change induced by the Dam construction and it depends on factors other than the capability of the land for agriculture.

The Upper Brisbane Valley to the north of Wivenhoe lies in a rift valley which is filled by later deposits to considerable depths. The eastern shore line of Wivenhoe Dam lies near to the eastern (West Moreton) fault zone.

The construction of some very large dams in other countries has been followed by seismic activity in their areas, with evidence that such activity has been related to the water body. The activity has mostly been light but in the case of some which were built in earthquake prone areas, for example in Greece, quite serious earthquake shocks have occurred.

There are two potential causes of seismic activity when dams are first filled. One stems from the actual load applied by the impounded water on the underlying strata, which can disturb an existing state of equilibrium and create excessive local stresses in the rock. The other stems from the influence of pressure from water which builds up in fault planes or shear zones, inducing movement in the adjacent strata either by lubrication or redistribution of loading.

It is now accepted world practice to check for seismic activity in connection with major dams where these exceed 100 metres in height, or have a storage capacity in excess of 1.2×10^9 cubic metres. Wivenhoe Dam falls within this latter category. The Co-ordinator-General's Department, after consultation with the Department of Geology, University of Queensland, has arranged for the Queensland Department of Mines to carry out seismic observations over a period of years before loading and after construction has been completed. Although some adjustment of the underlying strata will most probably occur, only minor scale activity is anticipated.

The core and filter arrangement proposed in the Dam should be such that small movements of the structure will not threaten its structural safety. This has been considered and appropriate design measures have been taken.

5.2.2 Upstream Flooding

The major upstream effect of the flood storage is the creation of an area of some 10 000 hectares around the lake which will be subject to occasional flooding. A buffer area, above full supply level, greater than the area occasionally flooded is being acquired and this will be leased for grazing in the future. More intensive land uses such as agriculture should not be allowed in the buffer area because of possible erosion and contamination effects.

5.2.3 Sedimentation

Potential sources of soil sediment deposition in the catchment are clearing, cultivation, excavation and filling for roads and housing, sheet erosion, landslips, stream erosion and overgrazing.

The relative importance of any of these sources will vary throughout the catchment, and will depend on the slope and nature of surface materials. Preliminary studies by the Department of Primary Industries indicate that sedimentation is unlikely to seriously deplete the storage capacity under present watershed conditions over the foreseeable physical life of the structure. The condition of the watershed should, nevertheless, be subject to regular surveillance.

The construction of the Dam will cut off the normal bed load of sediments which would otherwise pass the site of the structure. As a result, some degradation of the river bed downstream of the Dam can be expected. Because of the reduction in flood magnitude and flood frequency as a result of the Dam, the effect is anticipated to be minor.

5.2.4 Water Quality

There is a major difference between the situation applying to the urban water catchments in the Moreton Region and those applying in the urban water catchments of most other Australian capital cities. In the Moreton Region, approximately 86 per cent of the total area is privately owned and occupied and is very largely under freehold tenure. Some 60 per cent of the Region will ultimately form the watershed areas upstream of water supply dams, and inhabited and developed watersheds are accepted as normal in the Region. All major urban supplies receive treatment and chlorination prior to use.

The maintenance of water quality in the proposed Dam depends on the extent of buffer lands acquired around Wivenhoe Dam, and their future use. Water quality also depends on the restraints that might be applied to more remote lands, with respect to cultivation, the use of fertilisers and pesticides and intensive stock activity. Early interdepartmental discussions showed that there were differing opinions and a lack of basic data on which to make informed judgments.

A 'Wivenhoe Dam Catchment Area' was declared under the Irrigation Act 1922-1973 and the Water Act 1926-1973 for the purpose of controlling land subdivisions and land uses which could degrade the water quality in the Dam.

The Co-ordinator-General's Department initiated in July 1973 a very detailed long term study of water quality in the Brisbane River catchment upstream of the proposed Dam. The Stanley River, the Brisbane River, the important tributaries flowing into each, and the water in Somerset Dam are sampled at monthly intervals and flows at each sampling point are estimated or gauged. Over a period of some years this will provide information as to the total composition of the water, the effects of seasonal variations, flow variations, and other pertinent data. There are in all over thirty sampling points, although some are not sampled as frequently as others.

Testing, by arrangement, is being carried out by the Brisbane City Chemist, using City Council laboratory facilities. The testing covers a broad field, under several main headings. An example of the form of a monthly report is attached as Appendix 4.

Somerset Dam is the oldest major storage in the Moreton Region. Little record exists as to how the ageing of the lake may have affected the quality and properties of the stored water over the years. Virtually all of the water consumed ex Somerset Dam is released at the Brisbane City Council's discretion and flows down the Brisbane River over a distance of some 130 river kilometres, mixing with other water before reaching the Mt. Crosby Water Treatment Works pumping pool. Unless flood conditions prevail, lower level water is allowed to flow from Somerset Dam. The composition of this water is documented in the series of analyses recorded in the Wivenhoe Dam water quality project. Somerset Dam exhibits algal blooms seasonally and the released water smells strongly of hydrogen sulphide at the release area at times.

Brisbane drinking water meets World Health standards and comprehensive monitoring of reticulation with respect to health aspects is routine. There has been little change in handling methods for Somerset Dam water over some thirty years. There has been minimal regular monitoring of raw water above Mt. Crosby until the advent of the Wivenhoe Dam water quality project.

The 130 river kilometres between Somerset Dam and Mt. Crosby aerates and conditions the deoxygenated water released from Somerset Dam. The City Council samples Brisbane River water at Kholo and this gives early warning of likely adverse effects in the Mt. Crosby Pool and allows preventive steps to be taken. Problems with metals such as manganese and iron seldom arise, but there have been suggestions of near nuisance levels at isolated intervals.

Regardless of future land use in the upper watershed, Wivenhoe Dam, like Somerset Dam, will be subject to algal blooms and deoxygenation of the water will occur at depth. Water discharged from Wivenhoe Dam will be softer and less saline than the mix of Somerset Dam water and the uncontrolled Brisbane River flow because Wivenhoe Dam will store much of the softer surface runoff now lost after heavy rain.

Aspects requiring further study are:

(a) the effect of Somerset Dam releases on Wivenhoe Dam water quality;

(b) physical effects due to storage time;

(c) the effect at Mt. Crosby of a reduced river length of about 60 kilometres in which aeration and conditioning of the water can occur;

(d) the effect of different draw-off levels at Wivenhoe Dam on water quality.

Brisbane's major storages are constructed in catchments already used for rural production and no moves have so far been made to exercise land use control in their watershed areas. The watersheds concerned have been utilised for relatively non-intensive rural production which has not substantially changed with time and to date few problems have arisen. In the Somerset Dam watershed, an appreciable percentage of the area is under the control of the Forestry Department. There are no large towns. There were moves during the last speculative land boom to develop the upper catchment for rural residential type development and for some intensive subdivision adjacent to the lake of Somerset Dam. The construction of roads, housing, gardens, etc. in these types of developments could cause a siltation and water quality problem in adjacent storages. The Clean Waters Act safeguards water quality by controls on the discharge of effluents into streams. Other administrative actions which could provide the necessary controls to safeguard water quality are:

(a) the declaration of the 'Wivenhoe Dam Catchment Area' under the Irrigation Act and the Water Act. The area so declared includes the ponded waters as well as the flood margin and adjacent areas up to a short distance from the flood margin;

(b) the gazettal of a Town Plan for the Esk Shire.

5.2.5 Construction Materials

Exploitation of the gravels along the submerged river course by dredging in the shallow waters of the reservoir may be possible after construction of the Dam, provided that water treatment problems resulting from suspended sediment can be overcome. An evaluation of the river bed deposits and the likely gravel-bearing terraces is being undertaken by the Geological Survey of Queensland before the Dam is built, to provide data on location, quantity and quality. Detailed investigation of the higher, silty terraces need not be undertaken, as the removal of considerable thicknesses of silty and clayey over-burden by dredging would be too damaging to water quality and would probably be uneconomic.

The removal and stockpiling of gravels for future use, before the Dam is built, would be uneconomic, except for limited quantities for local needs.

The small quarry near Dundas could continue at its present scale without undue effect on water quality. Controls on working may be necessary should the quarry be expanded to a larger size.

5.2.6 Groundwater

In a reconnaissance investigation of groundwater supplies in the Brisbane Valley by the Geological Survey of Queensland - see Appendix 1 - it was reported that reasonable supplies of groundwater could be expected from the Cainozoic alluvium along the river, but that little development of such sources had taken place due to the ready availability of water for irrigation from the river itself. Most of the sources would be gravel beds in low terraces close to the river which would be recharged from the river. Alluvial flats suitable for irrigation upstream of the ponded area in the Upper Brisbane River will remain above water level, and existing irrigation in these areas will be allowed to continue. No further increase in irrigation will be permitted.

Groundwater supplies in the rocks of the Toogoolawah Group surrounding the reservoir are reported to be only minor, and in the case of the Neara Volcanics, of poor quality. The effect of the reservoir on supplies in these generally impermeable rocks will be minimal. Only a slight rise in water table immediately adjacent to the shoreline will occur.

5.3 INDIRECT PHYSICAL IMPACT

5.3.1 Land Capability in the Catchment

Land capability in the Catchment has been investigated by the Department of Primary Industries. The land use in the entire Dam catchment may, and the land use adjacent to a storage will affect water quality, turbidity and sedimentation in the storage. The more important factors that should be taken into account in assessing the effect of land use, etc. in the Wivenhoe Dam watershed on water quality are:

(a) Significant areas of the upper catchment are controlled by the Forestry Department and used for mainly non-intensive timber production;

(b) In general, intensive agricultural use of land which will not be submerged by the water body is restricted to relatively small areas of the river and creek flood plains;

(c) The Department of Primary Industries considers that adequate land is available elsewhere in the State to replace the agricultural and pastoral production on land which may be inundated or alienated from agriculture or grazing by 'catchment area' controls. Thus, the short term costs are the costs of enterprise displacement and the long term costs are the marginal increases in production costs and transport costs arising from production in other areas. The short term costs will be reflected in the price of water from the Dam;

(d) Controls needed to maintain water quality may modify existing rural production practices on properties in the catchment unaffected by the Dam and so impose economic costs on the owners.

In the past, the land use around the large dam supplying water to the Brisbane Conurbation has not caused significant problems. Some of the areas close to existing and future storages are capable of more intensive land use than is currently the case.

Careful management will be required to maintain the quality of the water flowing into, as well as the water ponded in the Dam. The creation of a totally controlled catchment (as in some southern States) would be difficult, given the existing level of development.

The possible important future land uses in the catchment are grazing, agriculture, forestry, urban development and recreation. Each of these uses could affect sedimentation, turbidity, and water quality. The current level of land use and development (primary production) within the catchment is satisfactory from the aspect of water quality, because of its non-intensive nature. However, some form of controls will be required to limit changes in land use to more intensive forms, such as feed lots, abattoirs, urban development, noxious industries, etc. New legislation will be needed if some measure of control is to be achieved over types of land use in the catchment that would adversely affect water quality and reduce the life of the Dam.

5.3.2 Agriculture

Due to Queensland's climatic conditions, land cannot be used for intensive rural production without increasing erosion to a level above that occurring under natural conditions. Agricultural practices that increase the soil salinity, the sediment pollution of water courses, the flooding of downstream areas and the siltation of dams will affect water quality and could justify some form of control on their use. The economic production of certain crops requires the use of pesticides and/or fertilisers and it is not possible to keep these out of the surface and subsurface waters. Water quality will therefore be adversely affected. The effects of fertilisers, pesticides, etc. could warrant controls on their use in areas adjacent to the Wivenhoe storage.

The major fertiliser elements likely to be used in the area are nitrogen and phosphorus. Phosphorus is highly absorbed by most agricultural soils. High fertiliser rates on soils with a low ion exchange capacity may result in a significant output of soluble phosphorus in direct surface drainage. Phosphorus is, however, unlikely to reach Wivenhoe Dam in this form except from areas adjacent to the storage.

Many forms of nitrogen are soluble and highly mobile. They are transported readily in surface runoff and they may become included in subsurface water. Either method of transport will increase nitrogen levels in downstream water storages.

Water quality testing carried out to date, as part of the Wivenhoe Dam water quality project, has established the presence of appreciable amounts of phosphorus and nitrogen. A quantitative examination has shown that the amounts present are very much greater than the total amounts of added fertiliser over the whole catchment. The main source of phosphorus would appear to be country rock, while plants, especially legumes such as wattles, are the main source of nitrogen. Current low-intensity land usage in the catchment has apparently not significantly altered natural water quality.

A major part of the Wivenhoe Dam catchment has been cleared and is used for grazing and the level of fertiliser use at present is low. A large area of the flats used for lucerne growing will be acquired for the ponded area. So long as the grazing use of the catchment continues to be extensive, nitrogen fertiliser use is unlikely to increase and the nitrogen level in the storage will mostly arise from the natural flora. Nitrogen levels could rise if commercial fertiliser companies encouraged an increased use of nitrogenous fertilisers in the area. The proximity of the Wivenhoe area to both fertiliser plants and product markets could make it a prime target for such a programme. Control on land use around the Dam, through the Local Authority Town Plan, could ensure that water quality deterioration would not occur due to fertiliser use.

5.3.3 Cattle Dipping

The catchment of Wivenhoe Dam is located within a cattle tick area where regular dipping or spraying for tick control is necessary. The Biarra tick which is resistant to traditional dips occurs in part of the catchment. The main chemicals now in use for tick control (chlorinated hydrocarbons are prohibited) are organic phosphates, but a small number of arsenical dips are still in use in the catchment area. A double strength organic phosphate dip is required for the Biarra tick.

The Department of Primary Industries estimated in 1972 that in the Wivenhoe Dam catchment, excluding the catchment of Somerset Dam, there were 272 dips with a total capacity of 3.4 megalitres, 19 dips of unknown capacity, and some about which there was no knowledge. The total capacity of all dips could be about 4.0 megalitres.

The dip chemicals now in use - see Appendix 5 - are of low mammalian toxicity and are not significantly persistent in biological systems. Dipping operations are such that the escape of chemicals is minimal.

Within the area of land to be acquired for water supply and flood storage, there are about 40 existing dips with an estimated total capacity of about 0.5 megalitres. Many of these dips will cease to exist but those that are relocated should be carefully sited to ensure that they do not affect water quality in the future. All dips that will be inundated or will have to be relocated because they are too close to the pond should be pumped out and neutralised before water storage commences. If in the future dip chemicals can be shown to adversely affect water quality then legislation would be needed if controls on dip chemical use in the catchment are considered necessary.

5.3.4 Forestry

Both State forest and private forest operations occur in the catchment above the Dam. Some clear felling takes place on private land. It may be possible to control clear felling through Town Planning provisions. If not, and if clear felling is likely to cause erosion such that sediment problems occur in the lake, then special legislation may be needed.

Tree plantations close to the foreshore of the Dam may be possible, although their economic viability and the suitability of the land for this use has yet to be established. Should entomological pests occur in any tree plantations established close to Wivenhoe Dam, the Authority controlling the Dam should be consulted before any chemical spraying of forestry plantations is undertaken. Modifications to establishment procedures may also be necessary so as to reduce sediment output if tree plantations are to be established close to the Dam foreshores.

5.3.5 Recreation

Major bodies of water within 80 kilometres of a large metropolitan area have a high recreational potential. A large water storage dam could be used for a wide range of recreational activity, e.g. boating, sailing, fishing, water skiing. Lakes are aesthetically pleasing as environments for picnicking, walking, etc. and they make nearby land areas attractive as places where people would like to live.

The use of artificial lakes for recreational purposes is well developed in the United States of America and it is receiving increasing attention in other western countries. Arguments against such use centre around whether bacteria and viruses are introduced into the water, thus creating a health risk. Bacteria are removed in the treatment process by chlorination and the major part of the cost of treatment is in treating turbidity, tastes, metals, etc. It is possible that viruses could be introduced into the water and pass through subsequent water treatment processes without being detected or removed. Different methods of sterilising water are under development now and it is likely that positive viral sterilisation will be available in the future. In the United States of America about 70 per cent of artificial lakes are used for recreational purposes - all of these of course are not urban water supply dams.

The water flowing into Wivenhoe Dam will come from settled areas and in passing from the Dam to Mt. Crosby the water will flow through settled areas, so pollutants could be picked up from sources other than from the recreational use of the Dam. The recreational use of the waters of the Dam, under supervision, should be developed by the Authority responsible for the control of the Dam or in collaboration with the Authority.

An outdoor recreation capability assessment has been undertaken to study the existing recreational situation and the recreational potential following the construction of the Dam (11), (13). About 300 kilometres of shoreline and about 10 000 hectares of water surface will be created by the Dam and the area could develop into a major recreational resource in the Moreton Region.

Approval has been given to acquire about 800 hectares of land in the Wivenhoe Hill area for recreation purposes. This will provide a large area on the lake shoreline suitable for activities such as picnicking and walking, as well as providing suitable sites for boat launching ramps, etc. If boating is allowed on the lake, the sites in the Wivenhoe Hill area should be adequate for the demand in the early years of the life of the Dam. In the future, additional boat launching ramps elsewhere on the lake may be needed.

Incompatible water based recreational uses, e.g. water skiing and fishing, should be separated. Those who want to use the Dam waters for recreation purposes could be required to join a club based on the Dam, so that the Authority responsible for the Dam can acquire control over the use of the lake and supervise that use. The lake has a potential for bathing, boating, sailing, fishing, water skiing, canoeing, although not all possible uses might be permitted. At present, under certain flow conditions, the reach below Somerset Dam provides a 'white water' canoeing area. This will disappear when Wivenhoe Dam is completed, although it may reappear in periods of low water storage in Wivenhoe Dam. No natural features exist in the river that would provide 'white water' canoeing immediately downstream of Wivenhoe Dam.

Water based recreation uses can contribute to pollution in the Dam, e.g. petrol and oil slicks from power boats or bacteria from body contact sports. An area of the lake, immediately upstream of the Dam wall, should be banned for any kind of water based recreation. This area should be large enough to give the water some time to 'cleanse' itself before being drawn into the water supply system.

5.3.6 'Rural Residential' and Rural Development

A number of small communities exist now in the Dam catchment and they provide services for the various rural pursuits that occur in the area. The population associated with these rural activities is small and if the Dam was not built it could be expected that the present situation would continue with a small population decline associated with property aggregation and more capital intensive management of properties.

The Dam and its proximity to Brisbane will increase the potential of the land adjacent to the foreshores for non-rural uses such as 'rural residential' subdivisions. Although some existing farms will cease to exist, if these non-rural uses are permitted there may be a net population increase. The maintenance of water quality in an urban water supply dam is important. 'Rural residential' sites carefully selected according to suitable geological, soil and terrain characteristics and sufficiently distant from the lake, should not cause sediment problems if care is taken during the construction period. The major impacts of urbanisation on water quality are pollution caused by waste disposal systems, dumping of solid wastes, street runoff, high rates of application of weedicides, pesticides and fertilisers to gardens, etc. Some of the chemical contaminants that might occur cannot be economically removed in water treatment. The present population upstream of the Dam wall introduces sewage and septic tank effluent and urban runoff into tributary streams. This causes no problems at the treatment works at Mt. Crosby from a biological point of view. The Wivenhoe Dam water quality testing already shows a substantial build up of pesticide and biological contamination levels downstream of urban areas. Any increase in the number of houses close to the lake foreshore should be discouraged so as to maintain water quality. Monitoring of water quality should continue to determine if controls will be needed in the future.

Additionally, linear development of residences around the lake, while providing lake views to the occupants of those residences, would impair the visual amenity of the lake that all, in the absence of such residences, could enjoy.

Control of development and changes in land use in the area close to the Dam could be effected through the Esk Shire Town Plan. It will make some provision for control of land uses and development on the area of land surrounding the lake, i.e. subdivision size, intensive uses such as piggeries and feed lots, chemical applications to land etc. It might prove necessary to have some control on the number of houses that could be built on each single block of land. At present there is no legislation which requires Local Authorities to take Town Planning measures to protect water quality in existing or proposed dams.

5.3.7 Effect on Flora and Fauna

The Dam site and the area to be inundated by the Dam have been extensively cleared for pasture and cultivation. The Department of Primary Industries (14) sees no objection to the proposed Dam from a botanical point of view. No adverse effects on mangrove areas in tidal reaches will occur.

A number of species of fish live in the waters of the Brisbane River and of these the long-finned eel and the sea mullet require access to the sea to breed. Eels, however, move overland under favourable conditions to pass Somerset Dam and it is expected that they will do this around Wivenhoe Dam. The height of the proposed Dam and fluctuations in dam storage levels make a conventional fish ladder impracticable. If the catchment above Wivenhoe Dam is to be permanently blocked to access by sea mullet, it will mean their disappearance from the Esk and Toogoolawah districts.

The sea mullet is the principal commercial food fish found in Queensland waters and forms one-third to one-half of the landings of fin-fish in the State. Although essentially marine, this species spends the greater part of its early life in freshwater streams, and the Brisbane River is one of the three most important mullet rivers in the State. The Dam will deny access to about half the freshwater habitat currently available to mullet in the Brisbane River watershed. Although an accurate assessment is impossible, the Fisheries Branch of the Department of Primary Industries - now the Queensland Fisheries Service - estimates that conceivably this could result in a reduction of the order of 10 per cent in the Region's mullet run. See Appendix 2. The potential loss to the industry in that case is estimated to be about $100 000 annually. The actual loss is likely to be very much less than this, since only some of the fish using the upper waters of the river will eventually be included in the mullet catch.

Thomson - see Appendix 3 - believes there is no evidence that construction of Wivenhoe Dam will have any great effect on the quantity or value of mullet commercially netted by the fishing industry in Moreton Bay or adjacent thereto. He considers the number of mullet line fished as a pastime in the Upper Brisbane River is unimportant in economic terms.

Appendix 2 presents a most pessimistic view of the impact of the Dam on the sea mullet stocks and the fishery while Appendix 3 presents a more optimistic view. A definitive statement would require prolonged field investigations over many years. The effect of existing weirs and dams on mullet stocks in the Moreton Region is unknown because adequate statistical information is lacking. Fewer fisherman are now producing at least as much mullet as a greater number of fishermen in the past but this may in whole or in part be due to improvements in equipment.

A fish lift could be built into the Dam at a cost of, at least, $500 000 . There is some doubt as to whether such a device would be effective in maintaining mullet upstream of the Dam wall and if the mullet would use it to move down the river. Interest and redemption charges per year on the investment, at present interest rates, would be at least $50 000 per year and the annual value of the State mullet fishing dependent on the freshwater upstream of the Dam would have to exceed that to justify the lift. Under the circumstances, a fish lift is not considered justified.

The Dam will provide a very large lacustrine habitat less than 80 kilometres from Brisbane. If a suitable fish species could be introduced to the lake, and provided that the Authority in charge of administration of the Dam permits angling activities therein, it would be possible to develop freshwater angling opportunities close to the main concentration of the State's population. Thomson - see Appendix 3 - considers that yellow-belly would be a suitable choice (among others) in any fish stocking programme.

5.3.8 Effect on Archaeological Sites

The distribution and nature of aboriginal relics within the ponded area of the storage have been outlined previously. The Department of Aboriginal and Islanders Advancement (12) suggests that a detailed survey be undertaken before construction begins to record and possibly remove relics that would be affected by the Dam and associated activities, including the relocation of services.

5.4 ECONOMIC AND SOCIAL IMPACT - UPSTREAM OF THE DAM WALL

5.4.1 Number of Properties Affected and Acquisition Policy

Details of the properties which will be totally or partially acquired are shown in Table 5.1.

TABLE 5.1

NUMBER AND AREA OF PROPERTIES TO BE TOTALLY OR PARTIALLY ACQUIRED

	Number
Properties to be totally acquired:	
. Holdings greater than 0.4 hectare	146
. Holdings less than 0.4 hectare	14
. Allotments in Town of Somerset Dam	25
	185
Properties to be partially acquired	53
Total number of properties affected	238

Source: Co-ordinator-General's Department.

So as to allow investigations to proceed, e.g. at the Dam site or on road relocations, or where owners wished to proceed to the Land Court, resumption procedures have been used. Generally, the land for the inundated area and flood margin will not be required before about 1980. Where properties are totally acquired, owners will have to find new properties if they want to continue in rural industry. Where properties are partially acquired, owners will have to rearrange the working of their properties and they may need to acquire extra land if their enterprise is to remain economic. The Government decided that landowners could ask to be acquired earlier than when their land would be needed, and if money was available, settlement would be made. The land acquired would be leased back on a short term basis to the existing owner, or, if he left the area, preference in leasing would be given to other affected landowners. This policy gives farmers time to find another property, provides the funds to buy that property, and gives them an income while getting their new property into production.

Properties that remain viable in the long term after their productive flats are acquired will have to scale down their operations or increase the purchase of feed. Net income will fall. Owners whose properties are partially acquired may be able to buy the remnant areas of other partially acquired properties to increase their property size, and they may also be able to lease back land acquired as the flood margin for the Dam. After the Dam is built and storing water, the productive flats will be no longer available and aggregations of acquired lands are proposed in such a way as to make viable units for grazing purposes, with long term leasing arrangements. Only grazing will be permitted on flood margin land. The Government has decided not to increase irrigation entitlements elsewhere on the Brisbane River to compensate for the loss of production due to the inundation of affected lands.

5.4.2 Agricultural Production - Inundated Area

In 1970 the Economic Services Branch of the Department of Primary Industries assessed the net agricultural production for the inundated area for two alternative dam sites and five dam sizes (4),(15). The evaluation was based on a survey of approximately one-third of the farmers likely to be affected. Gross margins per acre for irrigated and dry land crop production, costs of growing forage crops and pastures, as well as gross margins for livestock enterprises, were outlined in that survey report.

The aggregate gross margin, fixed costs and net returns for a dam at Wivenhoe, with land acquired to EL 76.2 AHD, are shown in Table 5.2. Source quantities have been converted to metric units.

TABLE 5.2

AGRICULTURAL PRODUCTION AND NET RETURNS AS AT 1970
From land required for Wivenhoe Dam

	Units	Dam at Wivenhoe EL 76.2 AHD
Lucerne Hay	tonnes	18 880
Maize	tonnes	1 415
Potatoes	tonnes	152
Sorghum	tonnes	108
Butterfat	kg	138 400
Pigs	No.	14 768
Vealers	No.	1 090
Beef Cattle	No.	1 269
Aggregate Gross Margin	$	833 730
Fixed Costs	$	346 451
Net Returns	$	487 279

Source: Department of Primary Industries (15).

The net annual value of agricultural production lost therefore was estimated to be $487 279 in 1970. A complete reworking of the data using current prices and farm practices would be necessary to update the results obtained in Table 5.2. This is not feasible, because, since 1970, farmers in the area have been affected by the inevitability of the construction of the Wivenhoe Dam. Farm production plans as a consequence have already altered and further development of farms which will eventually be acquired has stagnated.

Downward trends in butter and milk production were already well established prior to 1970, independently of planning for Wivenhoe Dam. Announcement of plans for the Dam may have accelerated this trend.

In the 1970 analysis, no attempt was made to evaluate the effect that future trends in agricultural production would have in the absence of the Dam. Dairying was declining in importance and the area under lucerne hay was increasing. Since then, the decline in dairy production has caused the closure of the Esk butter factory.

Without the Dam, suitable areas of the land now to be inundated would probably have been used in the future for horticultural activities because of the proximity to Brisbane.

Land acquisition has been in hand since 1973. All the land of 185 properties, 146 of which exceed 0.4 hectare in area, and some of the land of another 53 properties will be required. The 1970 analysis was based on an estimate of a smaller number of properties and the net value of agricultural production has therefore been underestimated. This may be partially offset once the Dam is constructed, when land that has been acquired but which is not needed for the lake is aggregated into productive holdings.

5.4.3 Local Businesses

Local business houses will be affected by loss of expenditure from land holders who will leave the area after their properties are acquired and by the alteration in expenditure patterns of those land holders whose properties are acquired but who will retire within the area. The most important loss will be due to the out-migration of many farmers and the out-migration of rural workers who will not find jobs because of the reduction in the agricultural area.

Table 5.3 presents survey data collected by the Department of Primary Industries in 1970 and shows the likely reduction in expenditure over various categories and in various towns. Column 2 gives an indication of 1974 values by updating the 1970 estimates using the Bureau of Agricultural Economics "Index of Prices Paid by Farmers - Queensland" and the Consumer Price Index.

Assuming that there will be a total loss of expenditure from 146 properties (i.e. there are 146 properties with greater than 0.4 hectare), the drop in farm expenditure would be approximately $1.8 million in 1974 money values. The main town to be affected will be Esk, with a weighted average of 51 per cent per farm expended in the town. Toogoolawah will be adversely affected by the loss of machinery sales and servicing.

TABLE 5.3

AVERAGE YEARLY EXPENDITURE PER FARM

Item	Value of 1970 Purchases		Place of Purchase (% of total spent)				
	in 1970 values $	in 1974 values $	Esk	Toogoolawah	Ipswich	Brisbane	Other
Machinery	2 500	3 217	13	75	-	-	12
Machinery Repairs	2 000	2 451	56	44	-	-	-
Fuel & Oil	1 000	1 116	87	5	8	-	-
Feed Seed & Fertiliser	1 000	1 294	87	5	8	-	-
Groceries	1 500	2 126	72	2	10	8	8
Clothes	200	306	61	-	20	19	-
Household Articles	200	274	45	-	37	18	-
Car	1 000	1 442	33	17	33	17	-
Car Repairs	200	288	77	23	-	-	-
Weighted Average of All Items			51.67	32.30	7.85	3.79	4.37
TOTAL	9 600	12 514					

Note - Based on data collected in 1970 from a sample of affected farms.

Source: Department of Primary Industries (15).

5.4.4 Properties Not Affected by Land Acquisition for the Dam

These properties could be affected in a number of ways:

(a) A few local properties will lose the benefit of obtaining necessary inputs at low haulage costs, e.g. cream and milk cartage, lucerne, grains etc. The expenditure pattern of these properties will change and properties on the eastern side of the Dam may direct their purchases more towards Ipswich than Esk.

(b) The loss and the subsequent re-routing of a number of existing roads may reduce access to any one property or between various parts of one property as well as between other properties. However, this will occur in only a few pockets. Generally, relocated roads will be of higher standard than those formerly existing and will certainly have a higher degree of flood immunity.

(c) On completion of the Dam, values of properties around its periphery might increase. If subdivision of existing properties into 20 hectare blocks is allowed, values could exceed those based on primary production.

(d) The eight or nine existing farms supplying cream on the eastern side of the Dam will be affected. Some will be acquired, leaving a balance of three or four farms. This could make cream collection from these remaining properties uneconomic.

(e) Some school bus routes will be longer. This effect, coupled with the reduction in the number of school children, could make the provision of school bus services more costly.

(f) Some small local churches will probably close.

Compensation is not payable if the property is not required for the purposes of the Dam.

5.4.5 Esk Shire Council

With the construction of the Wivenhoe Dam, an important area of the Esk Shire will be flooded. The proposed full storage level will cover an area of about 10 700 hectares, equivalent to about 2.8 per cent of the total Shire area. At the maximum flood height the corresponding figures are about 17 200 hectares and about 4.5 per cent. Because of the need to acquire a margin above maximum flood height and to acquire non-viable remnant areas of properties, the total land acquired will increase to about 31 000 hectares or about 8 per cent of the total Shire area. This will represent a drop of about 24 per cent in the number of rural holdings in Esk Shire and a reduction in the revenue of the Council raised by rates and other charges. Once the Dam is completed this revenue loss may be partially compensated by the increased rateable value of some properties overlooking the Dam, but this will be determined by the policy with respect to subdivision of rural land surrounding the Dam.

The Council will also be affected by the need to relocate a number of roads.

The major impact of the Dam on the Shire will be on rate revenues. It can be argued that covering the land behind the Dam with water for urban water supply is a higher use of land than its present use. It could also be argued that the users of the water should pay rates to the Esk Shire Council. There is no legislation in existence at present that requires the users of the water to compensate Esk Shire for the loss of rate revenue.

5.4.6 Population

The 1971 census showed a decrease in the population of Esk Shire but the 1976 census showed a slight increase due to residential subdivision of the southern part of the Shire. The estimated population at 30th June 1976 was 5 970.

Some farmers, whose properties are acquired for the Dam, will seek to re-establish themselves in primary production elsewhere. Since few properties are available locally, this will mean a migration from the Esk Shire. Other farmers whose properties are totally acquired may seek retirement and it is possible that some may retire to Esk, Toogoolawah or Lowood.

An estimate of the potential out-migration of the rural population from the 185 properties totally acquired is 703. Apart from the effect such out-migration will have on local business incomes, mentioned earlier, it is estimated that 21 per cent, or 148 persons, are school age children in the age group 5 - 15.(15). This may lead to staff reductions in some schools.

The temporary presence of numbers of construction workers and the permanent presence of supervisory and maintenance staff at the Dam and pumped storage sites will counteract, to some extent, the fall in rural population, but they are unlikely to outweigh local out-migration in the long term.

5.4.7 Labour Force

At 30th June, 1971, there were 2 275 persons in the labour force in Esk Shire and of these 50 per cent were employed in agricultural industry. The wholesale and retail industry and the construction industry employed 11 per cent and 9 per cent of the labour force respectively. It is estimated by the Department of Primary Industries (15) that the labour force employed in agricultural industry, apart from the owners of the properties, will fall by about 90 persons as a result of the Dam. This figure makes no allowance for any workers who could become unemployed on the 53 'partially acquired' properties because of a decreased level of operation.

A reduction of this size in the labour force in the agricultural industry will mean that some workers will have to seek work outside of Esk Shire and this might mean that some will leave the Shire.

5.4.8 Multiplier Effects

The Department of Primary Industries calculated employment multipliers for the Esk Shire using employment in various industries as indicated by the Census of Population and Housing. The basic sector was defined as the primary industries grouping. Employment multipliers for Esk Shire are shown in Table 5.4.

TABLE 5.4

EMPLOYMENT MULTIPLIERS FOR THE ESK SHIRE

Workforce in:	1961		1966		1971	
	Males	Total	Males	Total	Males	Total
Primary Industries (Basic Sector)	1 326	1 482	1 147	1 465	929	1 148
Secondary Industries (Non Basic Sector)	117	132	123	139	114	135
Tertiary Industries (Non Basic Sector)	681	925	660	953	657	973
Total Workforce	2 124	2 539	1 930	2 557	1 700	2 256*
Employment Multipliers	1.6	1.7	1.7	1.7	1.8	2.0

* Earlier figures for the 1971 labour force include 19 persons unemployed.

Source: Department of Primary Industries (15).

Past research has shown that economic base multipliers tend to over-estimate multiplier effects so that the employment multipliers above may over-emphasise the impacts. Multipliers based on the female labour force have not been calculated since female employment in the Shire is small and tends to fluctuate and hence it provides an unstable base for multiplier calculation.

If it is assumed that in Esk Shire the male workforce of 929 employed in primary industries is evenly distributed between the rural holdings then a reduction of 24% in the number of rural holdings will lead to an estimated decrease of approximately 222 males employed in primary industries. An estimated decline of about 222 males employed in primary industry will result in a total of about 399 males losing employment if a multiplier of 1.8 is used. That is, the impact of 222 males in primary industry losing their income is the loss of employment of a further 177 males in the Esk Shire. Employment on the dam site could ease this indirect employment in the short term while in the long run the improved job opportunities resulting from increased tourist activity and dam maintenance will reduce the impact of lost employment caused by the flooding of rural holdings.

No attempt has been made to calculate multipliers to assess changes in output and income. Changes in output and income will not be felt immediately but will gradually work their way through the local economy. Compensation is not payable for indirect losses.

5.4.9 Social Life and Other Effects

The decrease in the rural population as a result of the Dam will have an effect on the social life of the area. There will be fewer people and therefore less job opportunities for young people, more of whom will have to leave the Shire to live and find work. Older farmers whose properties are totally acquired and who retire to the smaller towns will increase the number of old people in those towns and increase the services required for the aged. The construction force employed on the Dam could be a temporary annoyance to the residents of the small towns close to the Dam should they go to those towns in search of entertainment.

When the Dam is completed, expenditure generated by people travelling from the larger urban areas for recreation purposes could increase the revenue of some local businesses such as petrol stations, cafes, etc. Businesses serving mainly farming interests will not gain any extra income from this source.

SECTION 6

AN ASSESSMENT OF THE IMPACT OF ROAD RELOCATIONS ON THE EXISTING ENVIRONMENT

6.1 SYNOPSIS

The impact on the environment of the road relocations made necessary by the construction of the Dam is assessed. The Brisbane Valley Highway and the Esk-Kilcoy Road, both of which have to be relocated over certain sections, are under the control of the Main Roads Department. A major relocation of Shire Roads on the eastern side of the future lake is required because some existing roads will be cut by the water behind the Dam.

6.2 INTRODUCTION

The water ponded behind the Dam will cover six bridges over the Brisbane River and a number of other bridges over tributary streams and thus make a number of existing roads impassable. Some lengths of roads on either side of the river, which run generally parallel with the river will also be cut by ponded water. About sixty-nine kilometres of road, some under the control of the Main Roads Department, will have to be relocated. The major roads and bridges affected are:

(a) Brisbane Valley Highway and the bridge over the Brisbane River at Wivenhoe. The pond will be too wide and deep to provide a new crossing on the existing location.

(b) Esk-Kilcoy Road and the bridges over the Brisbane River at Murrumba and Marshall's Bridge over the Stanley River. The pond will be too wide and deep to provide new crossings on the existing locations.

(c) Watt's Bridge, Macfarlane's Bridge and the North-brook Bridge over the Brisbane River. All these bridges will be abandoned and the only cross river connections will be on the proposed new route of the Brisbane Valley Highway and on the new route of the Esk-Kilcoy Road. Marshall's Bridge across the Stanley River will be replaced by a new bridge closer to Somerset Dam.

A number of Shire roads including the Bryden Road that will in part be submerged by the lake will also be relocated.

All the new roads will traverse country that has been cleared and used for grazing and there should be little effect on the native flora and fauna. The cuts and embankments on the new roads will provide some sediment flow to the lake and some turbidity in the water in the lake close to the margin, at least in the first few years. The lake is so large that these effects will be of no consequence to water quality. All new sections of road will give greater flood immunity than the present roads. The sections of road relocated will be built to a higher standard.

6.3 BRISBANE VALLEY HIGHWAY

A length of about twenty-one kilometres of this highway will be relocated. The new road will leave the old road about one kilometre south of the present Wivenhoe Bridge over the Brisbane River, cross the river on top of the Dam, and then keep to the west of the existing highway and the inundated area, to rejoin the existing highway about one and one-half kilometres south of Tea Tree Creek. The cost of building a new road on this location to the same standard as the existing road will be borne by the Wivenhoe Dam project and this cost will be reflected in the price of water. The cost of upgrading the new road to modern standards suitable for the projected traffic volumes will be borne by the Main Roads Department. The new location for the road traverses, in some cases, properties that are affected by the Dam and the acquisition of land for the new road has been carried out at the same time as the acquisition of land for the Dam. Elsewhere, separate resumption action has been necessary.

6.4 ESK-KILCOY ROAD

A length of about twenty kilometres of this road will be relocated. The route of the relocation will be to the north of the existing road and it will be about the same length as the section of the road it replaces. A major high level bridge will be built on the new route at O'Shea's Crossing of the Brisbane River. This new bridge will provide the future cross river connection for not only the area served by the Esk-Kilcoy Road but for the area upstream served by the road crossing at Watt's Bridge.

The cost of constructing the road on the new route to the existing standard and of the new bridge over the Brisbane River will be borne by the Wivenhoe Dam project and so will affect the price of water. The cost of upgrading the road to present day standards will be borne by the Main Roads Department. The route of the new road mostly passes through land that has been or will be acquired for the purposes of the Dam - usually because, as a remnant area, the property is no longer viable. In a few cases in properties that are affected by land acquisition for the Dam but which are still viable, a separate acquisition will have to be made for the new road and in about three cases land will have to be acquired on properties not affected by land acquisition for the Dam.

6.5 ROADS UNDER THE CONTROL OF THE SHIRE

A number of Shire roads will be affected by the lake behind the dam and about twenty-eight kilometres of new road will have to be built. The Wivenhoe Dam project will carry the cost of building, to at least the same standard, Shire roads that have to be relocated. Reconstruction will be to the standard of construction presently adopted by the the Shire for its road works, which in some instances will be superior to the existing standard of the road replaced.

Watt's Bridge upstream of O'Shea's Crossing was washed away in a flood a few years ago and it has not been rebuilt by the Shire because a bridge at the height of the old bridge would be subject to frequent inundation by the lake. A short road connection on the eastern side of the river between the area served by Watt's Bridge and the Esk-Kilcoy Road would be cheaper than a new high level bridge on the site of the old bridge, and it would also provide a quicker and shorter connection to Woodford for milk and cream suppliers in the Watt's Bridge area. This road connection will be built as a charge to the Wivenhoe Dam.

An existing road - the Bryden Road - paralleling the river on the eastern bank connects the Esk-Kilcoy Road to the Brisbane Valley Highway at a point just north of the Wivenhoe Bridge. While a large length of this road will be unaffected by the ponded water, three sections will have to be relocated. One of the relocated lengths of road will leave the Brisbane Valley Highway about two kilometres south of the dam site and will follow the Pryde Creek valley to the Pumped Storage Project site and it will rejoin the existing road near Northbrook Creek. A short length of this road, because of the narrow spur on which it is located, passes very close to the deep part of the pool behind Split-Yard Creek Dam. Guard rails should be placed along this length so as to ensure that vehicles that leave the road cannot plunge into the water. This relocation will need to be built early since it will provide the access to the Pumped Storage Project. Any extra construction costs on the part of this road that is the access to the Pumped Storage Project, because of the wide and heavy loads that will have to be transported over it, will be a charge to the Pumped Storage Project. A little to the north of Northbrook Creek a small deviation, including a new bridge, is required at Deep Creek. At the northern end of the road a major relocation involving new bridges over Reedy Creek and the Stanley River is required to connect to the new route of the Esk-Kilcoy Road. This road will complete a road system that will allow motorists to drive completely around the lake, and, as it will allow panoramic views of the lake at some points, it could generate some extra traffic. Road distances between properties on the eastern side of the river and Esk or Toogoolawah will be longer after the Dam fills because the only crossings of the Brisbane River will be on the Brisbane Valley Highway and the Esk-Kilcoy Road.

Existing roads that either cross the river within the ponded area or are submerged over part of their length will be either abandoned, or shortened to spur roads and maintained as access to properties. The Council will still have to pay the charges on some road and bridge works built in recent years from loan funds and which will be no longer used after the lake fills.

Most of the land needed for the sections of Shire roads which have to be relocated has been obtained as part of the acquisition of land for the Dam. At the southern end of the Bryden Road near the Brisbane Valley Highway, necessary land has been acquired by resumption where properties are not affected by the Dam.

SECTION 7

AN ASSESSMENT OF THE IMPACT OF THE PUMPED STORAGE HYDRO-ELECTRIC PROJECT ON THE EXISTING ENVIRONMENT

7.1 SYNOPSIS

A Pumped Storage Hydro-electric Project will be constructed on the eastern side of the Dam. The impact on the environment of the Pumped Storage Project, both during and after construction, is assessed. The major impact will be on a small isolated patch of rain forest. Although isolated, it is not unique in the Brisbane Valley. There is no alternative site for the powerhouse, and construction procedures for the excavation should, as far as possible, seek to minimise adverse effects on the remaining rain forest.

7.2 INTRODUCTION

The proposed scheme has been investigated and reported on by Shepherd and Meredith (8). The upper storage will be provided by a dam across Split-Yard Creek on the eastern side of the Brisbane River. The lower storage will be provided by Wivenhoe Dam. The pump and turbine silos (the powerhouse) will be located about midway between the two storages in a natural depression on the scarp adjacent to the Wivenhoe Dam inundated area. An open channel will be excavated from the silos out into the lake formed by Wivenhoe Dam to provide the depth and volume of water needed by the pumps and turbines. The conduit connecting the upper storage to the pumps and turbines will be in tunnel. The plant will be controlled automatically when in service. A report on environmental aspects associated with the project has been prepared by Sattler (16) who considers that the major impact will be the adverse effect on a small isolated patch of rain forest.

7.3 SPLIT-YARD CREEK DAM

The upper storage will be formed by a dam built across Split-Yard Creek and filled by pumping from the lower storage during periods of low demand on the thermal base load power stations. The dam is located in open eucalypt forest country presently used for grazing. Before the dam is filled an area a little bigger than the inundated area will be cleared of all timber so as to reduce the likelihood of damage to valves, pumps and turbines by timber. Some of the timber is suitable for pit props and could be sold and the remainder, if it cannot be sold, e.g. for sleepers, woodchips, or as timber, will be burnt. The dam will be an earth and rock fill type, built from materials obtained within a short distance of the site. Core materials will be obtained on the Brisbane River flats, filter materials from Northbrook Creek and other materials from the conduit tunnel, powerhouse excavation and lower channel excavation, if materials in those excavations prove suitable, and from quarries if extra materials are required. The excavation sites on the flats and in Northbrook Creek will be eventually covered by water and the excavation in the lower channel and the silos will also be mostly covered by water. Any quarry sites will remain in view but, because of the remoteness of the site, this should not be objectionable.

The run-off from Split-Yard Creek will not fill the dam. If a malfunction should occur and the pumps were to keep pumping instead of cutting out when the dam was filled to its operating level, the dam could overflow. An emergency spillway providing for such overflow to run back into Wivenhoe Dam will be constructed in a saddle north of the dam wall. The new road to be built as part of the Shire road relocation on the eastern side of Wivenhoe Dam, between the Brisbane Valley Highway and Northbrook Creek via the Pryde Creek Valley, will pass over the natural watercourse into which the spillway will discharge. The chance that the spillway will be needed is very small but, because a large volume of water could be discharged unexpectedly if it is needed, it could be dangerous to persons and animals. The watercourse might be fenced off and the bridge will be high enough not to be submerged by any spillway discharge.

During each generating cycle the water level in the pumped storage may vary quite quickly over a relatively wide range, depending on the rate of generation in the power phase, and the rate of pumping in the return phase. Fluctuations of the order of 10 metres in a period of about 5 hours will be quite usual. In emergency conditions, due to a system failure elsewhere, a total drawdown of the order of 30 metres in 24 hours would be possible. This rapid fluctuation in water levels will make the dam generally unsuitable as a biological habitat, and rule out entirely any recreational functions. The rapid filling and drawdown may cause slips on the banks of the pond behind the dam. These would not cause any problems in the operation of the upper storage but the scars might be unsightly and a screen of trees should be left, if possible, between the relocated shire road and the reservoir area. An excavated berm back-filled with freely draining rock running right round the storage at an appropriate level to reduce such slips is under investigation.

7.4 POWERHOUSE, LOWER CHANNEL AND CONDUIT TUNNEL

The silos comprising the powerhouse will be constructed on the scarp to the east of the lake formed by Wivenhoe

Dam, in a depression located in a small isolated patch of moist sub-tropical rain forest consisting of two types of scrub - 'Hoop Pine Scrub' and 'Bottle Tree Scrub'. These types of scrub were once widespread in the Brisbane Valley but very little now remains. The small patch of rain forest does provide a habitat for specific animal and bird species. Wivenhoe Dam when full will inundate some of this rain forest and the construction of the silos and the lower channel cannot be undertaken without destroying further areas of it. While construction procedures will be arranged to preserve as much of it as possible, the soil cover over the rock is quite shallow. There could be some sliding of this soil cover adjacent to the edges of excavations which would cause damage to the adjacent rain forest.

The rock from the excavations for the powerhouse and the lower channel, if suitable, will be used in the Split-Yard Creek Dam. This will require the access road to the powerhouse, from the new location of the Shire road running up Pryde Creek, to be built before the work on the powerhouse and lower channel commences. Any unsuitable spoil should be led to spoil banks that will be covered by Wivenhoe Dam when filled. This will not be possible in the case of some material from the conduit tunnel, and if this cannot be used in the dam wall it will have to be spoiled in the Split-Yard Creek Dam area. The conduit tunnel will pass through the spur that separates Split-Yard Creek from the Brisbane River flood plain and therefore for part of the way it will pass under some of the rain forest.

7.5 ACCESS ROAD TO THE POWERHOUSE SITE

The access to the powerhouse site from the relocated Shire road could be either a tunnel through the spur between Split-Yard Creek and the powerhouse site or a road along the spur. During the powerhouse foundation investigation the rain forest was damaged by a track that was cleared along the top of the spur and by a sidelong cut excavated along the end of the spur to provide access to the powerhouse site. The road access is considered to be much cheaper than a tunnel and it is proposed to use as much of the investigation access track and excavation as possible so as to reduce the amount of further damage to the rain forest. Any sidelong construction should be wholly in cut and the excavated material hauled clear of the rain forest before being dumped as spoil.

Because of the shallow cover of soil on top of the rock some slipping of topsoil at the top of the cuts is likely to occur. It may be necessary to take measures to stabilise the movement of the soil at the top of the embankment by small retaining walls etc.

7.6 OTHER ENVIRONMENTAL FACTORS

A pumped storage hydro-electric scheme uses electricity generated at off-peak periods to pump water to a higher level. At times of peak power demand the water is passed to a lower storage through turbines, thus generating electricity. Coal is burnt in thermal powerhouses to generate the electricity used in pumping, thus causing some pollution elsewhere. Pumped storage hydro-electric schemes have economies in peak load power generation because they can be operated automatically and hence require little labour compared with a thermal power station of the same size; they do not depreciate as quickly as would a thermal power station and they allow thermal power stations to be used more efficiently.

The water used is not lost to urban water supply except for some evaporation in the upper storage. During the initial stages of operation it is possible that the water in Split-Yard Creek Dam returned to Wivenhoe Dam will be discoloured because of the likely soil slips due to rapid drawdown. This may cause a small increase in colour and turbidity in Wivenhoe Dam. This is not likely to be a long term effect and it should have very little effect on the cost of water treatment at Mt. Crosby.

SECTION 8

SHORT TERM IMPACTS DURING CONSTRUCTION OF WIVENHOE DAM AND THE PUMPED STORAGE HYDRO-ELECTRIC PROJECT

8.1 SYNOPSIS

The impacts on the environment during construction are described. The effect on employment in the area by the number of jobs created by construction of the project and the effect of the construction camp are discussed. The works on existing roads to carry detoured traffic or to handle increased traffic volumes are set out.

8.2 CONSTRUCTION PROCESSES

Construction processes such as washing plants, concrete plants, gravel and clay pits, etc., are all potential sources of turbidity in the water and sedimentation in the river. Precautionary measures at the construction site, such as passing wash water from concrete machinery through settling ponds before discharge to the river, etc., should be enforced by the Constructing Authority to minimise the effects. The impact of the construction on water quality downstream of the Dam and particularly at Mt. Crosby should be minimal if such precautionary measures are enforced. No special problems are anticipated in water treatment at Mt. Crosby during the construction of the Dam. The methods proposed to divert flood waters so that the embankment will not be damaged during the construction period of Wivenhoe Dam would not increase the flood hazard downstream and will ensure little risk to the embankment during the construction.

8.3 CONSTRUCTION WORK FORCE AND CAMP

The total number of workers employed at any time on the construction of Wivenhoe Dam, the Pumped Storage Hydro-electric Project and the road relocations made necessary by the Dam is difficult to estimate. The peak number employed on the two major projects - the Dam and the Pumped Storage Hydro-electric Project - could reach 1 000 but, because of the construction period which provides for a spread in the awarding of contracts, it is likely to be much less. A camp will be required to house the supervisory staff of contractors working on the Dam and the Pumped Storage Hydro-electric Project as well as the staff of the various Government agencies employed on contract supervision. Camps for persons employed on the road relocation contracts, if needed, will be sited adjacent to the particular section of the road to be built.

Persons registered as unemployed at this time in Ipswich and the small towns in the area include sufficient numbers with the necessary skills to satisfy the labour requirements for the two major projects. It is expected that employment on the two projects will be sought not only by the unemployed in the area but by presently employed persons seeking longer term work prospects than their present employment provides. If, during the period of construction of the projects, unemployment falls in the local area and not enough workers are available locally, then increased accommodation will be needed to house workers brought in from outside the area. Because of the time needed to construct a camp, provision to allow a small number of workers to camp on the site should be included in any camp built for supervisory personnel. It has been decided to build a central camp, administered by the Irrigation and Water Supply Commission, to house not only supervisory personnel but also, to the extent found necessary, other persons employed on both projects by contractors.

The central camp will be located near Wivenhoe Dam where suitable land adjacent to the Brisbane Valley Highway occurs in that area. It will be sewered and the effluent will have secondary treatment. The small amount of effluent that will be produced by the camp should have no discernible effect on water quality at Mt. Crosby because of the large dilution. If care is taken during the construction of services, i.e. roads, housing benches, water, sewerage, telephone and power reticulation, there should be no appreciable effect on the turbidity of waters arriving at Mt. Crosby.

If a high percentage of workers on both projects travel to the work site from Ipswich and the Lowood area, traffic on the Brisbane Valley Highway between Ipswich and Wivenhoe Bridge will increase. The two large projects will also generate increased truck traffic bringing supplies, stores, materials, etc. to the projects and to the camp site. The movement of vehicles carrying personnel and stores, etc., between the camp and the Pumped Storage Hydro-electric Project will also increase the traffic on a short length of the Brisbane Valley Highway from Wivenhoe Bridge over the Brisbane River south to the road access to the Pumped Storage Project.

8.4 ROAD UPGRADING OR TRAFFIC DETOURS

Except for a short section at Fernvale, the length of the Brisbane Valley Highway between second Sandy Creek north of the Esk Turnoff on the Warrego Highway and Wivenhoe Bridge over the Brisbane River (especially the section north of the Fernvale Bridge to the camp) is below present standards for the present traffic volume. It should be upgraded, if possible, before major construction starts, so as to cater for the normal traffic plus traffic generated by the projects.

During the later stages of construction of Wivenhoe Dam the present Wivenhoe Bridge over the Brisbane River on the Brisbane Valley Highway will be inundated and highway traffic proceeding to the north of the Bridge will have to be detoured. This traffic could be detoured by building an expensive length of temporary road to cross the Brisbane River downstream of the site of Wivenhoe Dam. This deviation would have no further use after the Dam was completed and the highway was constructed in its final location on top of the Dam. It has been decided to detour the traffic, when necessary, over the following roads - the Fernvale-Lowood, Lowood via Patrick Estate to Coominya, and Coominya Connection to the Brisbane Valley Highway. Where these roads have a bitumen pavement less than eighteen feet wide now, they are being widened by Esk Shire Council to twenty feet wide with funds provided by the Wivenhoe Dam Project. This will provide a substantial permanent improvement to the road system in this part of Esk Shire. Detoured traffic will have to travel some miles further than if a detour was provided just downstream of the Dam site.

SECTION 9

AN ASSESSMENT OF THE IMPACT OF THE WIVENHOE DAM AND THE PUMPED STORAGE HYDRO-ELECTRIC SCHEME ON OTHER SERVICES

9.1 SYNOPSIS

Telephone and electricity distribution services in the area will be affected by the Dam and the needs of the Pumped Storage Hydro-electric Scheme. The present Esk Town Water Supply Scheme will also be affected by Wivenhoe Dam.

9.2 TELEPHONE SERVICES

At present, telephone services to residents on the eastern side of the proposed Dam cross the area to be flooded by the Wivenhoe Dam. The number of subscribers after the Dam is built will be substantially reduced. Telephone services will be relocated along the routes of the road relocations, where required, on the eastern side of the Dam as a charge to the Wivenhoe Dam project. These services will also be required in the Pumped Storage Hydro-electric Project area during and after construction. The relocation of the services will not cause any adverse environmental effects because they will be generally within the clearing for the new roads and they will be underground.

9.3 ELECTRICITY DISTRIBUTION

The Southern Electric Authority of Queensland will build new power lines to the Wivenhoe Dam site and the Pumped Storage Hydro-electric Project site for construction purposes.

The present distribution system will be cut by the waters behind the Dam so that the present power lines will require relocation. The Southern Electric Authority proposes to bring the power to the Wivenhoe Dam site from the Mt. Tarampa area. The new line will be permanent. The new line to the Pumped Storage site will become a permanent line also. These lines, where located outside of road reserves, will have little adverse environmental effect, since much of the country has been wholly or partially cleared for grazing purposes. Residents on the eastern side of the Dam will be serviced by a line from the Pumped Storage site.

A large switchyard will be needed near the Pumped Storage Hydro-electric Project area to distribute the power generated by the Project. The location of this switch-yard and the routes of the transmission lines from the powerhouse to the switchyard and from the switchyard to the local centres have not yet been decided upon and the environmental assessment will be carried out by the Southern Electric Authority of Queensland.

The cost of bringing power into the Wivenhoe Dam and Pumped Storage Hydro-electric project areas will be a charge to the projects. The cost of providing new power lines to consumers where these are due to the effect of the Dam will be a charge to the Wivenhoe Dam Project.

9.4 ESK WATER SUPPLY

The present pumping station for the Esk Water Supply and part of the length of the rising main will be submerged by the water impounded behind the Dam. The reconstruction of the pumping station, so that it can operate after waters are impounded behind the Dam wall, will be completed before water is stored in the Dam as a charge to the Wivenhoe Dam Project. The relocation of the length of rising main which will be covered by the impounded waters will be completed at the same time as a charge to the Wivenhoe Dam Project. The reconstruction of the pumping station and part of the rising main will not have any new adverse environmental effect since the new pumping station will be on the site of the existing pumping station and the new location of part of the existing rising main will be on land extensively cleared for grazing.

SECTION 10

URBAN WATER COSTS AND PRICES

10.1 SYNOPSIS

The construction of Wivenhoe Dam will have an impact on urban water prices (charges) in urban areas within the Brisbane Conurbation. While no definite statement can be made because of a lack of economic and financial data, it is possible to discuss, in general terms, trends in costs and prices. The relative merits of the current financing and pricing strategies can be evaluated. Possible pricing, financial and management objectives, in the long term, are discussed.

10.2 URBAN WATER COSTS AND CHARGES - A REVIEW

10.2.1 Introduction

The area to be provided with urban water from Wivenhoe Dam includes both existing and potential development over a large part of the Moreton Region. Local Authorities which already draw water from the Brisbane City Council's Mt. Crosby treatment works are the Cities of Brisbane, Ipswich and Redcliffe (in part) and the Shires of Moreton (where areas are contiguous to Brisbane and Ipswich Cities), Albert (north of the Logan River), Beaudesert (north of the Logan River) and Pine Rivers (in part). Caboolture Shire through Redcliffe City also has a small present demand. If their present urban growth continues, Gatton and Laidley Shires will need to find new sources of water and future supplies to each town could come from Wivenhoe Dam. Esk Shire obtains water for Esk from the Brisbane River in an area that will be ponded by the Dam. In the future, part of Redland Shire will need to be supplied from the Brisbane system. Caboolture Shire could also increase its demand for water from the North Pine River Dam and the associated Pine Rivers Shire system in the future. Approximately 11 per cent of the treated water from Brisbane City Council treatment works, i.e. Mt. Crosby and North Pine River Dam, is supplied to adjacent Local Authorities at the present time (19 748 Ml in 1974/75).

At this point in time there is no alternative to the construction of Wivenhoe Dam if extra storage is to be provided by 1981/82 and if the Pumped Storage Hydro-electric Project is to produce peak load power in 1983. Because of its size, and hence large cost, Wivenhoe Dam will have an appreciable effect on the cost of urban water and therefore on water charges in the area supplied now and in the future by the Brisbane City distribution system.

The Co-ordinator-General's Department has published a report (17) dealing broadly with existing and possible future storages in the Moreton Region and with costs and forecasts of trends in cost elements.

10.2.2 Current Financial Policy and Costs

The Brisbane City Council's water undertaking is by far the largest in the Region and only the data for that undertaking has been examined. Table 10.1 has been drawn up from Brisbane City Council Annual Reports. It sets out expenditures on the Council's water undertaking for a number of years since 1959/60 on the basis of administration, debt service, operation and maintenance and new works. Expenditure on recoverable works has been excluded. The Table shows that there has been little change in the percentage expenditure under the different heads except that new works funded from revenue show wide fluctuations.

TABLE 10.1

REVENUE EXPENDITURE - B.C.C. WATER UNDERTAKING

Year	Working Expenses				Debt Service		New Works from Revenue		Total excluding recoverable works
	Administration		Operating & Maintenance						
	$000	%	$000	%	$000	%	$000	%	$000
1959/60	292	7.6	1 690	43.7	1 591	41.2	289	7.5	3 862
1963/64	413	8.4	2 067	42.1	2 343	47.8	83	1.7	4 906
1964/65	530	9.9	2 284	42.6	2 466	46.0	85	1.5	5 365
1965/66	487	6.4	2 569	33.7	2 525	33.1	2 041	26.9	7 622
1966/67	568	7.3	2 833	36.3	2 652	34.0	1 751	22.4	7 804
1967/68	601	7.5	3 039	37.9	2 736	34.1	1 650	20.5	8 026
1968/69	634	7.5	3 404	40.0	2 811	33.0	1 660	19.5	8 509
1969/70	626	7.0	3 492	39.1	2 971	33.3	1 846	20.6	8 935
1970/71	711	6.7	3 954	37.3	3 242	30.5	2 703	25.5	10 610
1971/72	977	10.3	4 436	46.8	3 808	40.2	257	2.7	9 478
1972/73	1 035	8.1	4 801	37.7	4 452	35.0	2 433	19.2	12 721
1973/74	1 183	9.4	5 829	46.3	5 383	42.8	195	1.5	12 590
1974/75	1 555	9.9	7 851	50.2	6 213	39.8	9	0.1	15 628

Source: Compiled from Brisbane City Council Annual Reports.

Table 10.2 shows outstanding loan liability and debt service by year and debt service as a percentage of loan liability and interest as a percentage of debt service for each year. Interest (see Appendix 6) charges as a percentage of debt service are increasing because of high interest rates and the inflation in construction costs in recent years and possibly because of some debt deferral.

TABLE 10.2

LOAN LIABILITY AND DEBT SERVICE
B.C.C. WATER UNDERTAKING

Year	Loan Liability $000	Debt Service $000	Debt service as percentage of Loan Liability	Interest as percentage of Debt Service
1959/60	21 303	1 591	7.47	53.8
1963/64	27 622	2 343	8.48	58.7
1964/65	28 736	2 466	8.58	58.5
1965/66	29 771	2 525	8.48	59.3
1966/67	31 695	2 652	8.37	60.2
1967/68	32 591	2 736	8.39	61.4
1968/69	35 660	2 811	7.88	64.0
1969/70	37 341	2 971	7.96	65.7
1970/71	41 979	3 242	7.72	66.6
1971/72	48 211	3 808	7.90	67.3
1972/73	58 293	4 452	7.64	69.6
1973/74	66 327	5 383	8.12	69.7
1974/75	74 076	6 213	8.39	72.9

Source: Compiled from Brisbane City Council Annual Reports.

Table 10.3 shows the value of assets depreciated at 1% per year of the historic cost, loan liability, debt service and revenue, abstracted from the Annual Reports for 1963/64 and 1973/74 and as estimated for 1983/84. The estimate for 1983/84 has been based on the estimated costs of major headworks expenditures to 1983/84 as well as an estimate of reticulation expenditures to that date and includes some inflation allowance. The estimates for 1983/84 assume that the construction of Wivenhoe Dam is completed in 1981/82. Water charges would need to rise to provide the revenue estimated as needed to cover the estimated annual costs in 1983/84.

TABLE 10.3

FINANCIAL ESTIMATES FOR 1983/84
B.C.C. WATER SUPPLY UNDERTAKINGS

	1963/64 $m	1973/74 $ m	1983/84 $m (estimated)
Assets (at cost less depreciation)	39.35	115.15	292.0
Loan Liability	28.2	71.1	254.0
Debt Service	2.34	4.75	27.0
Revenue	6.0	15.1	53.0*

* Estimated as necessary to meet commitments.

Source: Co-ordinator-General's Department (18).

In recent years, in the United Kingdom and the United States of America, investigations have been made into water charges and the elements of cost that make up the charge. The upward trend in the money value of expenditure and charges, illustrated by reference to the Brisbane City Council's water supply undertaking, is occurring elsewhere in the world and can be expected because of:

(a) inflation and its effect on costs;

(b) higher operating and maintenance costs because of the age of a substantial part of the system;

(c) replacement from loan funds of worn out items at substantially higher money values than the original investment;

(d) recent loan interest rates are much higher than those applying to earlier loans reaching maturity.

Capital investment in water supply undertakings is mostly funded by loan raisings and the interest and redemption on each current loan is included as a part of the water charge. In times of severe inflation items that are worn out incur replacement costs much greater than the original cost. More money than the original loan is needed to cover the replacement cost and, if the water charge is related to the historic cost, the funds needed to make up the difference between historic and replacement cost will not have been built up. The overseas investigations mentioned above suggest that the difference between the historic cost and replacement cost should be found by an increase in the water charge to provide the reserve funds needed.

Capital investment in headworks etc. is very 'lumpy'. After a major headworks has been built it may be ten or twenty years before a major augmentation is necessary. Thus the water charge rises at the time of completion of the headwork and, as more consumers are added over time and more and more of the capacity of that headwork is utilised, the charge per unit to cover the cost of the headwork falls. The part of the water rate that covers headwork costs tends to rise by sharp steps as each new headwork is added to the system and this is especially so in periods of high interest rates and high inflation rates. Cossins (19) illustrates this with reference to the Brisbane City Council's water undertaking.

Currently water charges are related to costs and not related to the value of the water to various sectors of the community. This is a 'supply management' approach in that the water requirements of the users, based on low water charges, determine the requirements of the system and hence the costs and thus the charges. There is a danger that this approach could lead to over-investment in the water supply industry. Some investigators consider that this has in fact happened in a number of countries. A 'demand management' approach, where charges are based on usage as well as the value to the user, could result in less waste by users and thus in more efficient capital investment.

10.3 URBAN WATER STORAGE - WIVENHOE DAM

It is probable that Wivenhoe Dam as a source of urban water supply in a 'demand management' situation would not be needed by the early 1980's. Because of the long time needed to gain community acceptance of 'demand management' policies there is no alternative now to building the Dam. The implementation of a 'demand management' policy could extend the time when all the capacity of the water supply compartment is used.

It is essential that the water supply compartment in the Dam should be the most efficient size. Based on predictions of 'demand' by Cossins (2), Wivenhoe Dam will satisfy requirements to about 1992-95 in the absence of 'demand management' strategies. The next potential major storage is a site at Wolffdene on the Albert River which has a yield of about two-thirds of that of Wivenhoe Dam (4). The delivered cost of water from the Wolffdene Dam was assessed in 1971 as approximately the same as for Wivenhoe Dam (6). While this provided an argument in favour of the construction of Wolffdene Dam before Wivenhoe Dam, the ability of the Wivenhoe site to provide substantial flood mitigation for the lower Brisbane River Valley made Wivenhoe Dam the preferred next dam for water supply purposes for the Brisbane Conurbation.

The appropriate size of the urban water storage is not necessarily the minimum unit cost size, nor the storage of 'maximum' obtainable yield. The size should be determined only after a consideration of:

(a) the cost of water from future supplies in the light of future water demand forecasts; and

(b) the degree of the risk of depletion of supply from the Dam that can be tolerated and the confidence with which the risk can be stated. See Section 2.2.4.

Queensland practice for urban water supply purposes has been to adopt a risk of depletion of one per cent, in yield studies. In other Australian States, generally, a higher per cent risk of depletion is used. The adoption of a low degree of risk means that a higher capital investment in water storages is required for the same stated yield. These higher costs should be compared with the benefits of avoiding the shortages that the use of the low risk implies. The data which would allow such a comparison is not available.

Recently the Irrigation and Water Supply Commission (20) revised the yield estimates for the Wivenhoe Dam proposal on the basis of a statistical analysis of inflows into the Dam. The results confirm the findings of the analysis reported by the Co-ordinator-General's Department (4).

Results in Table 10.4 show the variation in the yield at Mt. Crosby due to Wivenhoe Dam as a function of storage capacity in the Dam for a one per cent risk of depletion. The yields vary, depending on the degree of confidence with which the one per cent risk of depletion is stated.

TABLE 10.4

WIVENHOE DAM - YIELDS (Ml/year) - FOR 1% RISK OF DEPLETION

Wivenhoe Storage Capacity - Ml	% Confidence			Historical Analysis
	99%	95%	90%	
500 000	100 000	115 000	140 000	115 000
750 000	140 000	155 000	185 000	170 000
1 000 000	165 000	185 000	215 000	225 000
1 100 000	170 000	195 000	230 000	245 000
1 150 000	175 000	200 000	230 000	250 000
1 200 000	180 000	205 000	235 000	255 000
1 300 000	190 000	215 000	245 000	265 000
1 400 000	195 000	220 000	255 000	270 000
Note: Somerset Dam	170 000	205 000	235 000	205 000

Source: Drawn from graphs prepared by Irrigation and Water Supply Commission (20).

In Table 10.5 the variation in the combined yield at Mt. Crosby assuming a 1 150 000 Ml storage in Wivenhoe Dam as a dual function of stated confidence level for a given risk of depletion is shown. The figure for 90% confidence, 1% risk of depletion, namely 461 200 Ml per annum, corresponds to a yield of about 230 000 Ml per annum due to Wivenhoe Dam as indicated in Table 10.4. That is, for this case the yields due to Somerset and Wivenhoe Dams are approximately the same. The analysis gives an indication of the sensitivity of the estimated of yield to risk.

TABLE 10.5

MT. CROSBY - YIELDS (Ml/year) - 1 150 000 Ml STORAGE AT WIVENHOE

Confidence	Risk of Depletion - %			
	0%	1%	3%	5%
90%	432 600	461 200	501 200	551 600
95%	385 300	402 200	444 600	506 800
99%	328 400	344 400	387 400	436 700
Historical Case	386 200	455 100	481 900	505 500

Source: Irrigation and Water Supply Commission (20).

The storage size has previously been decided as about 1 140 000 Ml (F.S.L. EL 67 AHD). It is not possible to examine, in economic terms, the optimum sizing of the urban water compartment of the Wivenhoe Dam because the necessary information is not available. Future surface water supplies in the Region are limited and, as supply costs are escalating, consideration should be given to the introduction of a 'demand management' policy. Such a policy would reduce the wasteful use of water and it would also provide the data needed for a better economic appraisal of future investment in storages.

10.4 URBAN WATER COSTS - WIVENHOE DAM

The Irrigation and Water Supply Commission (21) has estimated the total cost of a dam, in 1975 money values, as about $75m excluding capitalised interest. This estimated cost includes the cost of construction, land acquisition, relocation of services, etc. Including capitalised interest at 10 per cent, the cost is estimated to be about $102m. This cost, less Government subsidy, will reduce to $87m.

The existing water rate in the Brisbane Conurbation includes the cost of Dams reduced by the amount of the Government subsidy and includes the cost of flood mitigation built into the Dam. Cossins (2) estimates that the yield from Wivenhoe Dam will be fully utilised by about 1992. It is estimated that the cost of raw water averaged for the pumping pool at Mt. Crosby and the North Pine

River Dam is 1.02 cents per kilolitre as at May 1977. Assuming that the cost of flood mitigation in Wivenhoe Dam is included in the water rate, an estimate of the extra charge for water due to the cost of Wivenhoe Dam can be made. The estimates of the extra charge will be based on the assumption of a one per cent risk of depletion with 90% confidence, an interest rate of 10 per cent and an operating and maintenance annual cost of 0.25 cents per kilolitre.

Until the full yield of Wivenhoe Dam is utilised, the unit charge for water will be higher because the cost of the unused capacity will have to be paid by the existing consumers. Compared with the present estimated average cost of 1.02 cents per kilolitre for raw water, the estimated average cost of raw water when Wivenhoe Dam is first completed will be about 3.50 cents per kilolitre. The estimated cost of raw water will reduce to about 2.00 cents per kilolitre when the yield of Wivenhoe Dam is fully utilised.

10.5 IMPLICATIONS

The construction cost of Wivenhoe Dam will have a large impact on urban water costs in the Region. The costs of storing water in future dams however will be higher than in Wivenhoe Dam.

It is most probable that the water rate in the Brisbane Conurbation will rise quickly in the next decade. This rise will occur not only because of the cost of the necessary investments in future headworks and reticulation and the effect of inflation on costs, but also because the present system of water charges encourages unnecessary water usage. This encourages investment in new headworks before they can probably be economically justified. A pricing system that makes users aware of the cost of water through the charges for water should be encouraged. Loan funds for investment in water supply undertakings are scarce and likely to become scarcer and the investment of these loan funds should be guided by considerations of the value of the resource and economic efficiency. The National Water Council of the United Kingdom in a recent publication (22) states:

> "The water industry is a monopoly of a unique kind, the services are essential and few people have an alternative. Its activities are therefore not directly regulated by the market through competition of price and service as are commercial enterprises and in some sense other public utilities. More than usual effort is therefore required in investment policy to ensure that water services are not developed at a cost to the community that exceeds their value to the user. The need is reinforced by traditional reliance on methods of charging that afford most consumers no opportunity to influence their bills by their own economy of use."

As mentioned earlier, with the present system of water charges, Wivenhoe Dam is required by about 1982. There is no data available to estimate the consumers' reaction to a price based on usage and value, so it is not possible to determine if there is an economic need for the storage by 1982.

The analysis in this section assumes that the storages supply their rated yields and ignores the possibility that a succession of years with above average rainfall or below average rainfall could alter the time by which augmentation of the system is actually required. There is no way of evaluating this possibility.

10.6 FURTHER CONSIDERATIONS

In 1974/75 about 20 000 megalitres - approximately 11 per cent of the total amount of water supplied from Brisbane City Council water supply undertakings in that year - were supplied to contiguous Local Authorities. In future years the number of Local Authorities supplied with water is likely to increase and so is the quantity supplied expressed as a percentage of the total Brisbane City Council's supply, if the Council is prepared to meet the new demands. Local Authorities that have to rely for their urban water needs on the purchase of bulk water from another Local Authority can never be sure that the water they consider is needed will be supplied at the place and by the time they need it.

The Local Authorities contiguous to Brisbane City have much smaller populations than Brisbane City. Urbanisation in the contiguous Local Authorities will have a much greater percentage effect on a contiguous Local Authority's population than any likely population increase will have on Brisbane City's population. The rate of increase in water usage will be more rapid in the contiguous Local Authorities than in Brisbane City as a result.

This poses a difficult problem for the Local Authorities who now, or in the future, will draw water from Brisbane City's supply system. Brisbane City Council should have first call on all water resources financed by the Council and the Council also has the responsibility to ensure that enough capacity is reserved to cover the City's growth needs until the next storage is built.

One way by which a 'supplier' Local Authority can supply water to a 'purchaser' Local Authority is on the basis of an agreed price for treated water supplied in bulk at the boundary of the 'purchaser' Local Authority. The bulk price would include the cost ex treatment works plus the cost of transport through the 'supplier' Local Authority's mains. The agreement is likely to stipulate the maximum quantity to be supplied each year, the minimum quantity that must be paid for even if unused, and how the bulk water rate will be calculated. Provided that the 'purchaser' Local Authority can negotiate agreements for extra supplies as its growth requires, this method is the most advantageous to the 'purchaser' Local Authority, as it does not have to provide capital to construct headworks. The 'seller' Local Authority has to ensure that enough capacity is reserved for its own growth, but its biggest problem is to fix the charge to the 'purchaser' Local Authority.

The water rate will include the cost of water in bulk ex treatment works plus the cost of transportation to the point where the 'purchaser' Local Authority assumes responsibility for the water - usually the Local Authority boundary. The cost of transportation should include the extra cost of the larger sized main needed because of the 'purchaser' Local Authority's requirements. The bulk rate for water ex treatment works should include the cost to the 'supplier' Local Authority of providing in the past the capacity needed to supply the quantity needed by the 'purchaser' Local Authority. Thus over time each new negotiated bulk rate would include an increased charge per unit for the capacity provided in the past.

Alternatively the 'purchaser' Local Authority could make a capital contribution towards the cost of headworks at the time they were being built. In this case the agreement would stipulate the annual quantity of water the 'purchaser' Local Authority is entitled to as of right and how the bulk rate would be calculated. This method is probably the fairest for the 'supplier' Local Authority as it does not have to divert its capital funds to provide capacity in the future for other Local Authorities. In the case of 'purchaser' Local Authorities with small populations but rapid growth rates, the problem is to estimate how much water will be required by its population at the time the supply reaches capacity. This estimate influences the amount of capital that has to be provided initially. In Local Authorities with rapid population growths from a small initial population the capital needed initially could cause a very high water rate in the early years of supply.

If, as proposed, the Brisbane City Council finances the construction of Wivenhoe Dam, some of the funds invested will provide the excess capacity needed by other Local Authorities in the future and Brisbane residents will pay higher water rates initially. As the contiguous Local Authorities take up extra quantities of water in the future and provided the bulk water rate does include the cost of providing the capacity before it is needed by the 'purchaser' Local Authority, the 'supplier' Local Authority is recompensed for its earlier higher rates. However, in times of rapid inflation, if charges are based on historic costs, the 'supplier' Local Authority in effect subsidises the 'purchaser' Local Authority. This could be overcome if the charge included an amount to provide the difference between the historic and replacement cost of the system. A bulk water supply authority encompassing all the consumers in the distribution and supply system would appear to be able to spread the loan burden for headworks more equitably.

10.7 SUMMARY

The construction of Wivenhoe Dam should provide the water supply capacity needed by the Brisbane Conurbation up to at least 1992. Future supply sources will be dearer per kilolitre of water than Wivenhoe and in most cases they will be much dearer. Because of the effect of past and possibly future inflation on construction and operating costs and on replacement costs, and the possible shortage of loan funds in the future, a change in pricing policy should be considered so as to restrain the unnecessary use of water by consumers. The pricing structure, both for the bulk supply to Local Authorities and for supply by the Local Authorities to their consumers, should discourage the waste of water. A greater percentage of the capital works needed will have to be funded from revenue. A Water Authority might have to be established in the future to allocate water resources between Local Authorities and to spread the investment burden more equitably.

SECTION 11

FLOOD MITIGATION

11.1 SYNOPSIS

The proposed Wivenhoe Dam, as one of its major impacts, will reduce the flood hazard in the lower Brisbane River Valley. The extent of the reduction in flood hazard will be determined by the size of the flood storage compartment built in the Dam. This section discusses the factors, both economic and social, which were considered in selecting an optimum size of flood storage compartment. Recommendations for a combined structural/non-structural flood plain management strategy are outlined.

11.2 INTRODUCTION

In January 1974 the lower Brisbane River Valley experienced its worst flood since 1893. On three other occasions between 1841 and 1893, floods greater than the 1974 event occurred. In all, some 35 floods, high enough to be damaging, have occurred over the period 1841 to 1975. Somerset Dam on the Stanley River has mitigated, to a varying extent, severe floods since 1943. Unfortunately, its existence was interpreted by many within the community as a complete protection against flooding. The events of 1974 have reawakened in the community an awareness of the hazard due to flooding in the Brisbane River flood plain. This awareness is likely to diminish, however, if no floods occur in the next four or five years.

In the '1971' Report (4) the potential of the proposed Wivenhoe Dam for flood mitigation was recognised and a preliminary cost-benefit analysis was carried out. One of the conclusions of the report stated:

> "There is still a very grave flood risk threatening Brisbane and Ipswich and this can be greatly reduced by a suitably designed dam at Middle Creek or Wivenhoe."

The economic and social benefits determined at that time were sufficient to support a recommendation for a combined water supply-flood mitigation storage. The opportunity was taken after the '1974 flood' for the Snowy Mountains Engineering Corporation (23) to collect comprehensive flood damage information. The data was collected so as to estimate the potential flood damage (for the 1974 stage of development and for 1974 money values) for a wide range of floods, to enable a more accurate determination of the benefits from building a flood storage in the Dam. The study estimated that for the January 1974 flood, which rose to 5.45 metres at the Brisbane City Gauge, the total damage was $178 million.

Potential damage estimates on the same basis range from $10 million for a flood height of 2 metres at the Brisbane City Gauge to $531 million for a 10 metre flood on the same gauge. The estimated number of buildings affected by the January 1974 flood was about 13 000.

The potential flood damage in the urbanised areas along the Brisbane River is very high, even allowing for the flood mitigation effect of Somerset Dam. In addition to the potential financial losses, recognition should also be given to the danger to life during flooding, the social hardships during and after flooding and the worry and anxiety experienced by many occupants of the lower levels of the flood plain in periods of sustained heavy rainfall.

A reassessment of the value to the community of the flood mitigation potential of the proposed Wivenhoe Dam has been made using the results in the Snowy Mountains Engineering Corporation Report (23). However, to avoid continued encroachment into hazardous areas of the flood plain, based on a belief that the flood mitigation effect of Wivenhoe Dam will be greater than will actually be the case, complementary non-structural measures such as flood plain zoning are required.

11.3 FLOOD HYDROLOGY

The flood hydrology of the Brisbane River system is complex. Difficulties arise because of the spatial and temporal variation of rainfall patterns from one flooding event to another and the number of large tributaries feeding the system. The relatively few historic flooding events that have occurred since the start of wide scale data collection, the rapid changes in land use activity and development in the flood plain, the widening and deepening of river channels for navigation or by the winning of sand and gravel, the many changes in the river profile over time and the construction of Somerset Dam (which has influenced flood discharges since 1943) have added to the difficulties in analysis.

The effect of a flood storage in the Wivenhoe Dam on the flood hydrology of the lower river system has been considered in a number of publications in the literature - (4),(7),(23),(24),(25),(26) - and in a number of unpublished reports, e.g. by the Irrigation and Water Supply Commission (21). In these analyses to determine the flood storage volume, historic floods were routed through a number of potential flood storage sizes under a variety of assumptions as to operating procedures for both Somerset Dam and the proposed Wivenhoe Dam. While the dam site at Wivenhoe commands about 40% of the total Brisbane River catchment area, including the highest rainfall areas in the catchment, the catchment of the river not controlled by the proposed Wivenhoe Dam can cause, under certain rainfall conditions, substantial flooding in the urban areas of Ipswich City, Moreton Shire and Brisbane City.

Table 11.1 shows all historic floods since 1886 that have equalled or exceeded 1.2 metres on the Brisbane City Gauge, corrected where necessary to allow for the flood mitigation effect of Somerset Dam and adjusted to a standard tide condition. The Table also shows the effect of Somerset Dam on its own and the effect of Somerset Dam plus various flood storages in Wivenhoe Dam. The Table shows that even with a flood storage in Wivenhoe Dam, major flooding can still occur along the Brisbane and Bremer Rivers. However the probability of a flood of any given flood height at the Brisbane City Gauge will be significantly decreased.

TABLE 11.1

MAXIMUM ANNUAL BRISBANE CITY GAUGE HEIGHTS (METRES ON AHD)

1974 river conditions and flood plain development, and historic flood heights adjusted to a standard 2.0 m tide on Port Office Gauge*

Month/ Year	HEIGHTS					
	No Dams	Somerset Dam only	Somerset Dam + Wivenhoe Dam with Flood Compartments of - Ml			
			500 000	800 000	1 100 000	1 400 000
2/1893	7.20	5.60	4.90	4.00	3.40	2.80
1/1974	7.00	5.70	4.40	4.00	3.40	3.10
3/1890	4.75	3.40	2.50	1.75	1.20	
3/1955	4.35	2.65	1.20			
1/1898	4.25	2.70	1.50	1.20		
2/1931	3.25	2.35				
7/1973	2.80					
7/1889	2.72	1.54				
1/1887	2.60	1.46				
3/1908	2.50	2.10				
4/1928	2.45	1.94				
1/1968	2.02	2.00				
2/1951	2.00	1.74				
3/1947	1.94	1.74				
2/1971	1.84	1.22				
3/1950	1.84	1.56				
2/1896	1.52	1.38				
2/1972	1.50					
1/1927	1.46					
7/1954	1.30					
11/1959	1.26					
3/1956	1.24					
1/1929	1.20					

*Note: The Zero mark on the Port Office Gauge is 1.149 m below the Zero mark on the Brisbane City Gauge.

Excludes all floods where the river height in the case of 'no dams' was less than 1.2 metres.

Source: 1. Brisbane City Council (27)
2. Irrigation and Water Supply Commission (28)

Because of the short period of record (89 years) there is uncertainty as to the true probability of occurrence of floods of a given height in any one year, but there is general agreement that the estimates in Table 11.2 below, at least up to the 6 m height, are of the correct order.

TABLE 11.2

PROBABLE FREQUENCY OF FLOODING
(Log. Pearson Type III Distribution)

Brisbane City Gauge Height m A.H.D.	Probable Frequency				
	Somerset Dam only	Somerset Dam + Wivenhoe Dam with Flood Compartments of - Ml			
		500 000	800 000	1 100 000	1 400 000
2 m	1 : 11	1 : 25	1 : 30	1 : 35	1 : 40
4 m	1 : 28	1 : 45	1 : 50	1 : 60	1 : 70
6 m	1 : 60	1 : 70	1 : 95	1 : 135	1 : 200
8 m	1 : 110	1 : 250	v/rare	v/rare	v/rare
10 m	1 : 200	v/rare	v/rare	v/rare	v/rare

v/rare $\gg$ 1 : 250

Note: 1 : 28 represents the probable frequency of such a flood and means that there is one chance in twenty-eight that a flood of that height or higher will occur in any one year.

Source: 1. Snowy Mountains Engineering Corporation (23)
2. Irrigation and Water Supply Commission (28)

The heights of floods related to the Brisbane City Gauge can be converted into correspoding levels at any point along the River by means of flood profiles, published by Cossins (24), (26) and the corresponding inundation lines have been determined by the Snowy Mountains Engineering Corporation (23). These inundation lines are shown on the Flood Plain Maps for the Brisbane and Bremer Rivers published by the Department of Mapping and Surveying Brisbane.

After the flood storages have been called on to mitigate a flood, it will be necessary to discharge the stored water so as to empty the flood storages of both dams in readiness, should another flood occur. The operating procedure for Somerset Dam is to empty the flood storage in readiness for a second flood as rapidly as possible without causing unacceptable flooding downstream. The rate of release is increased as the flood caused by inflow from downstream tributaries falls off and the operation may, depending on the size of the flood, extend over some days. Large floods stored in Somerset Dam cut some roads in Kilcoy Shire for longer periods because of the need to keep the low level flood in the urban areas at a non-damaging level.

Wivenhoe Dam will have a flood storage of about twice the volume of Somerset Dam so that if the two storages are full and have to be emptied, at least three times the amount of water capable of being stored in the flood compartment of Somerset Dam will have to be released, following a major flood. If the acceptable level of low flood flows in Brisbane City corresponding to the emptying time for Somerset Dam alone is retained, then the emptying time for full flood compartments in Somerset Dam and Wivenhoe Dam together could be between one and two weeks. The low level of flooding due to the release of stored flood waters will be maintained for a longer period than in the case of Somerset Dam alone. In the 1893 flood, two major flood peaks occurred about a fortnight apart and in 1954 and in 1974 two cyclones less than a fortnight apart occurred in the South East Queensland area. If meteorological conditions indicate that a second flood is possible before the flood storages are emptied then they will need to be emptied at a faster rate to gain the maximum flood mitigation effect of the storages for the second flood. This would mean a higher prolonged low flood flow through Brisbane and the possibility that a minor flood level will be sustained after the flood peak has passed for a longer period than would occur with Somerset Dam only. The flood peak itself would be reduced in height due to the increased flood storage and total flood damage would be substantially reduced, but properties in the lower levels of the flood plain would be flooded for a longer period.

11.4 FLOOD DAMAGE

In 1974, following the '1974 flood', the Snowy Mountains Engineering Corporation (23) was commissioned by the Cities Commission to collect data on flood damage to all categories of affected property and to prepare stage-damage curves for a range of flood heights for each category of damage. The summary total damage table in the report is reproduced below as Table 11.3.

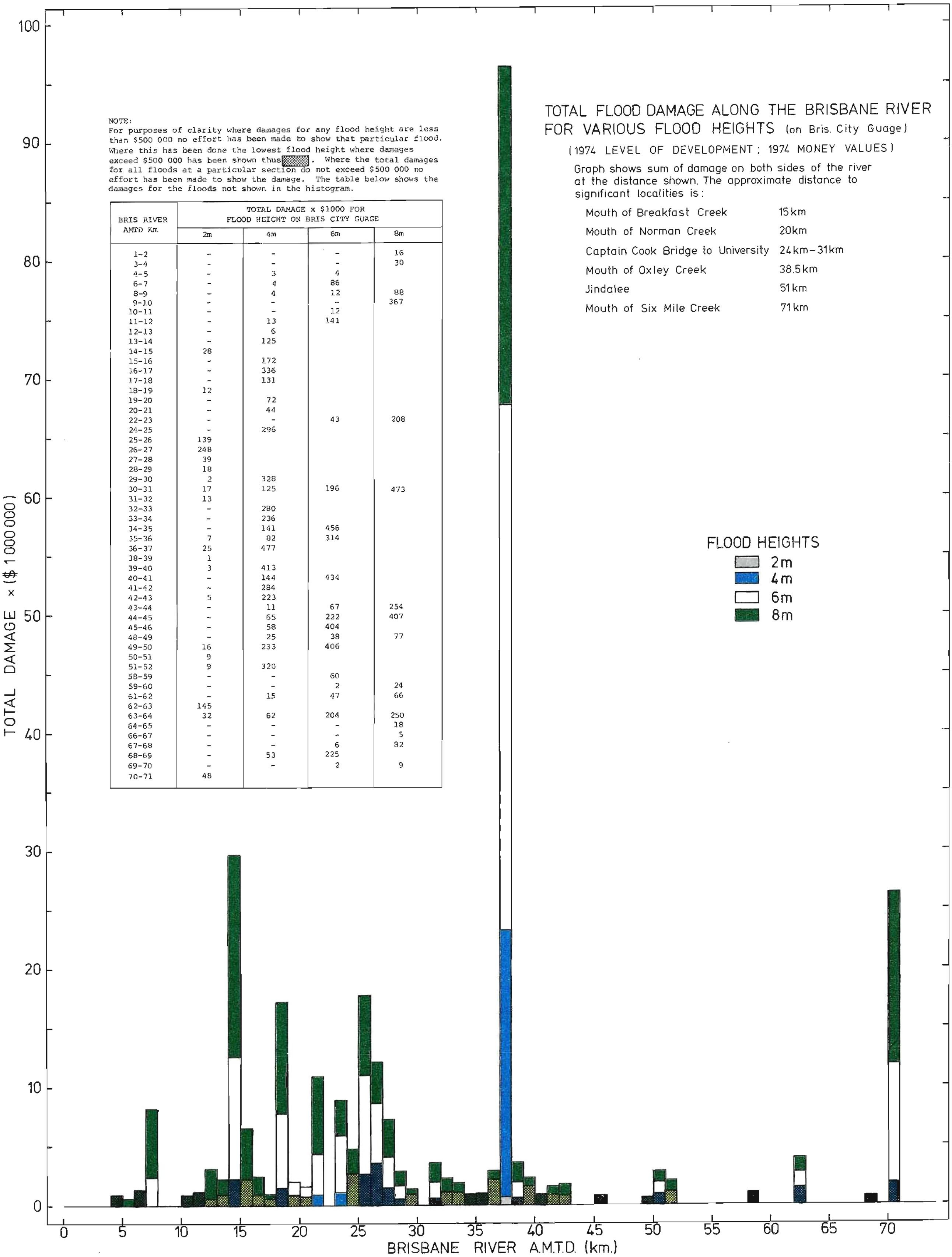
TABLE 11.3

ESTIMATES OF FLOOD DAMAGE (MID 1974 MONEY VALUES)
1974 Stage of Development

Flood Height m	Flooded Area km^2	Buildings Affected	Flood Damage - Million $	
			Direct	Direct + Indirect
2	12	470	8	10
4	57	6 700	67	83
6	102	15 300	173	217
8	153	23 500	288	362
10	205	31 000	426	531

Source: Snowy Mountains Engineering Corporation (23).

Figures 2 - 6 inclusive, plotted from data in the report,

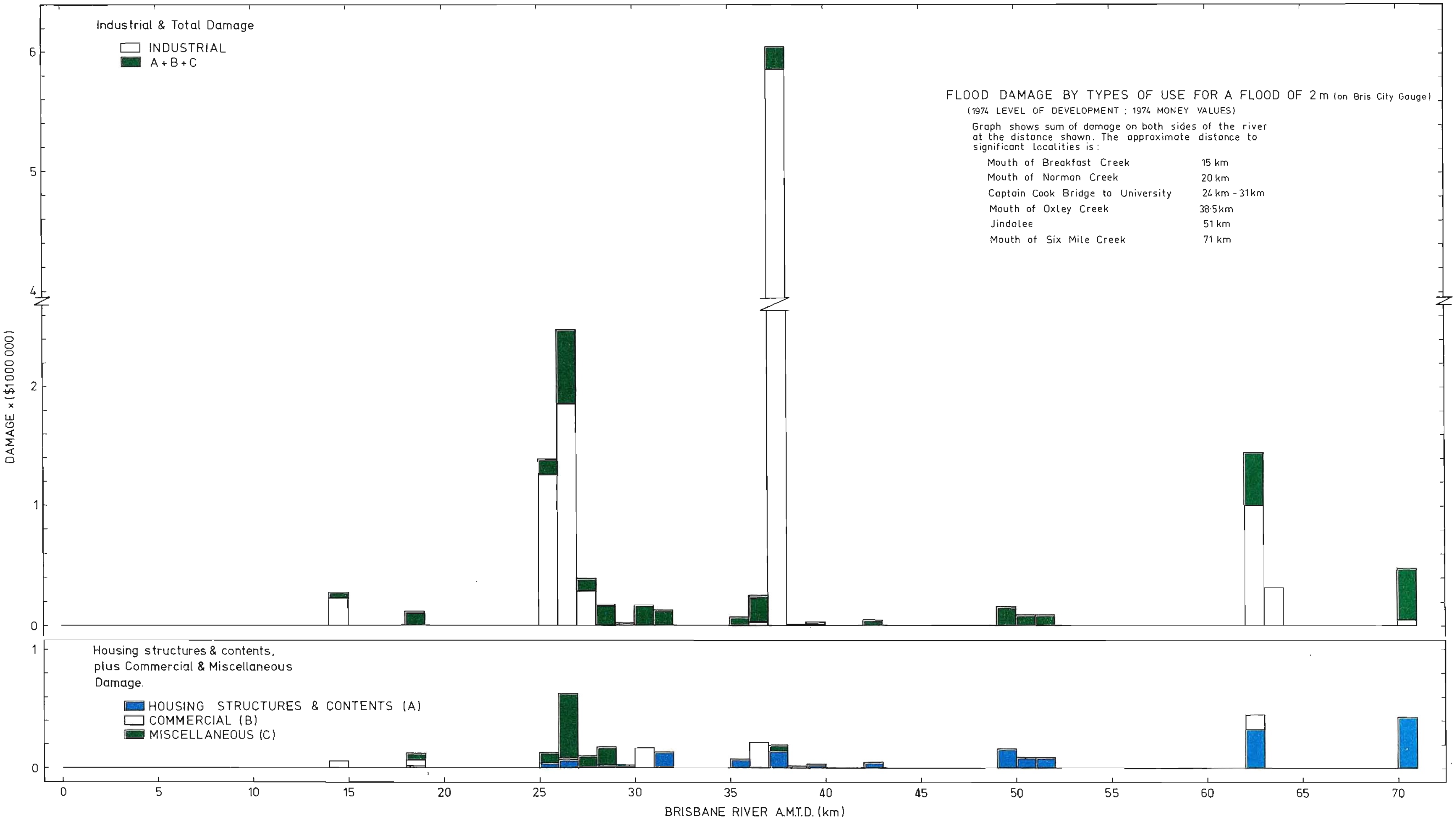


NOTE:
For purposes of clarity where damages for any flood height are less than $500 000 no effort has been made to show that particular flood. Where this has been done the lowest flood height where damages exceed $500 000 has been shown thus ▒. Where the total damages for all floods at a particular section do not exceed $500 000 no effort has been made to show the damage. The table below shows the damages for the floods not shown in the histogram.

BRIS RIVER AMTD Km	TOTAL DAMAGE x $1000 FOR FLOOD HEIGHT ON BRIS CITY GUAGE			
	2m	4m	6m	8m
1-2	-	-	-	16
3-4	-	-	-	30
4-5	-	3	4	
6-7	-	4	86	
8-9	-	4	12	88
9-10	-	-	-	367
10-11	-	-	12	
11-12	-	13	141	
12-13	-	6		
13-14	-	125		
14-15	28			
15-16	-	172		
16-17	-	336		
17-18	-	131		
18-19	12			
19-20	-	72		
20-21	-	44		
22-23	-	-	43	208
24-25	-	296		
25-26	139			
26-27	248			
27-28	39			
28-29	18			
29-30	2	328		
30-31	17	125	196	473
31-32	13			
32-33	-	280		
33-34	-	236		
34-35	-	141	456	
35-36	7	82	314	
36-37	25	477		
38-39	1			
39-40	3	413		
40-41	-	144	434	
41-42	-	284		
42-43	5	223		
43-44	-	11	67	254
44-45	-	65	222	407
45-46	-	58	404	
48-49	-	25	38	77
49-50	16	233	406	
50-51	9			
51-52	9	320		
58-59	-	-	60	
59-60	-	-	2	24
61-62	-	15	47	66
62-63	145			
63-64	32	62	204	250
64-65	-	-	-	18
66-67	-	-	-	5
67-68	-	-	6	82
68-69	-	53	225	
69-70	-	-	2	9
70-71	48			

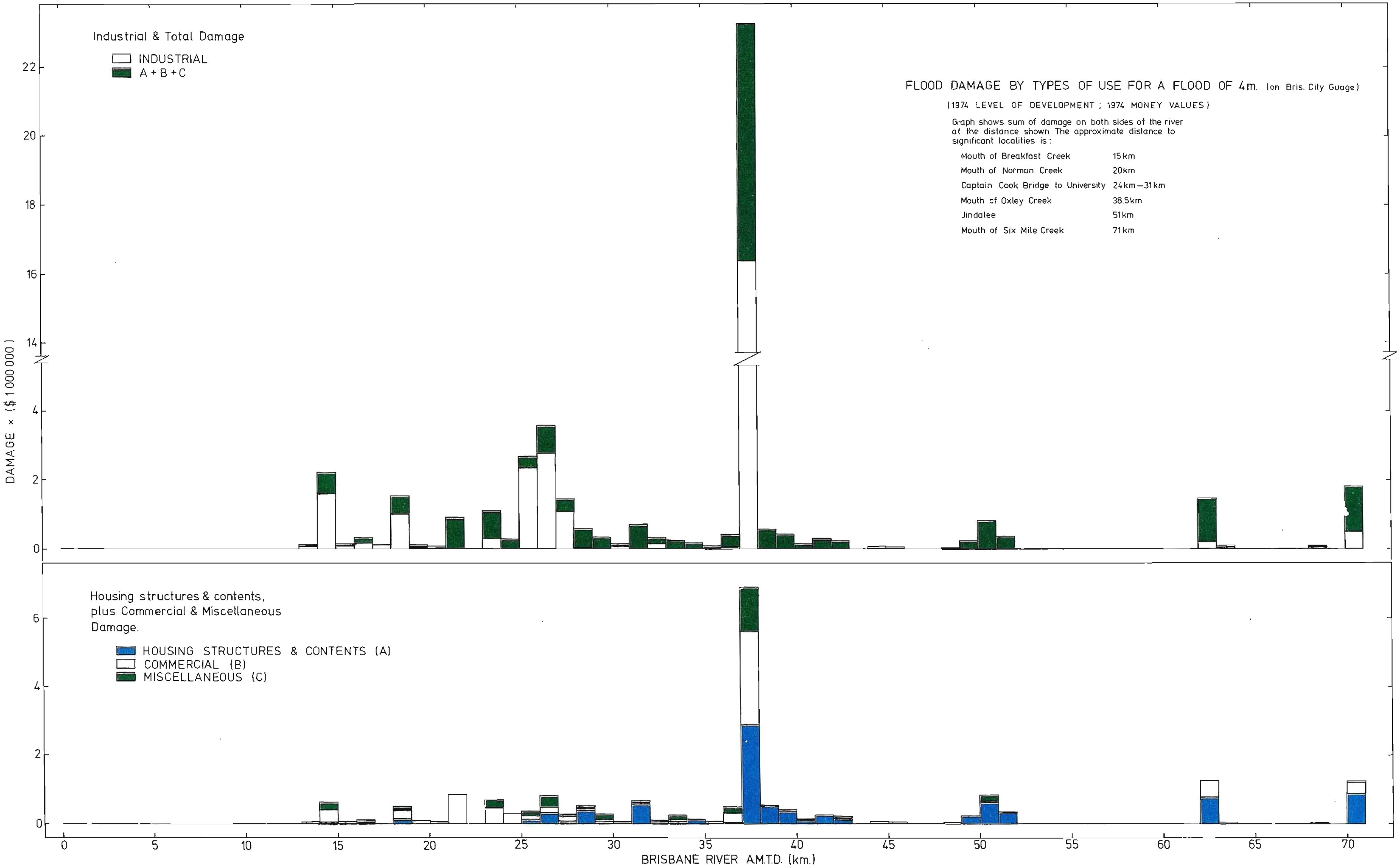
Plotted from data obtained by the Snowy Mountains Engineering Corporation for "Brisbane River Flood Investigations - Final Report", November, 1975

FIGURE 2



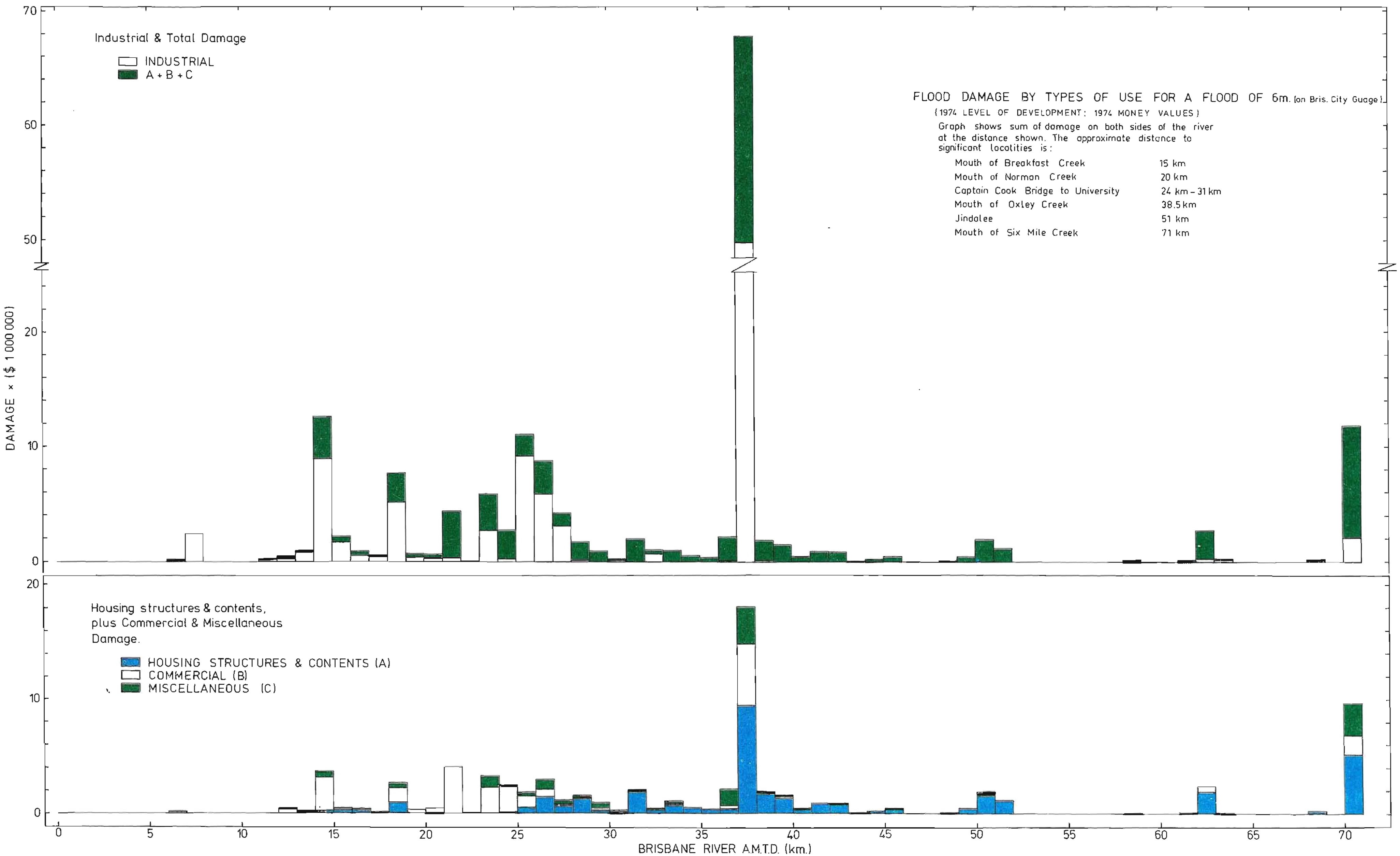
Plotted from data obtained by the Snowy Mountains Engineering Corporation for "Brisbane River Flood Investigations - Final Report", November, 1975.

2m FLOOD HEIGHT - FIGURE 3



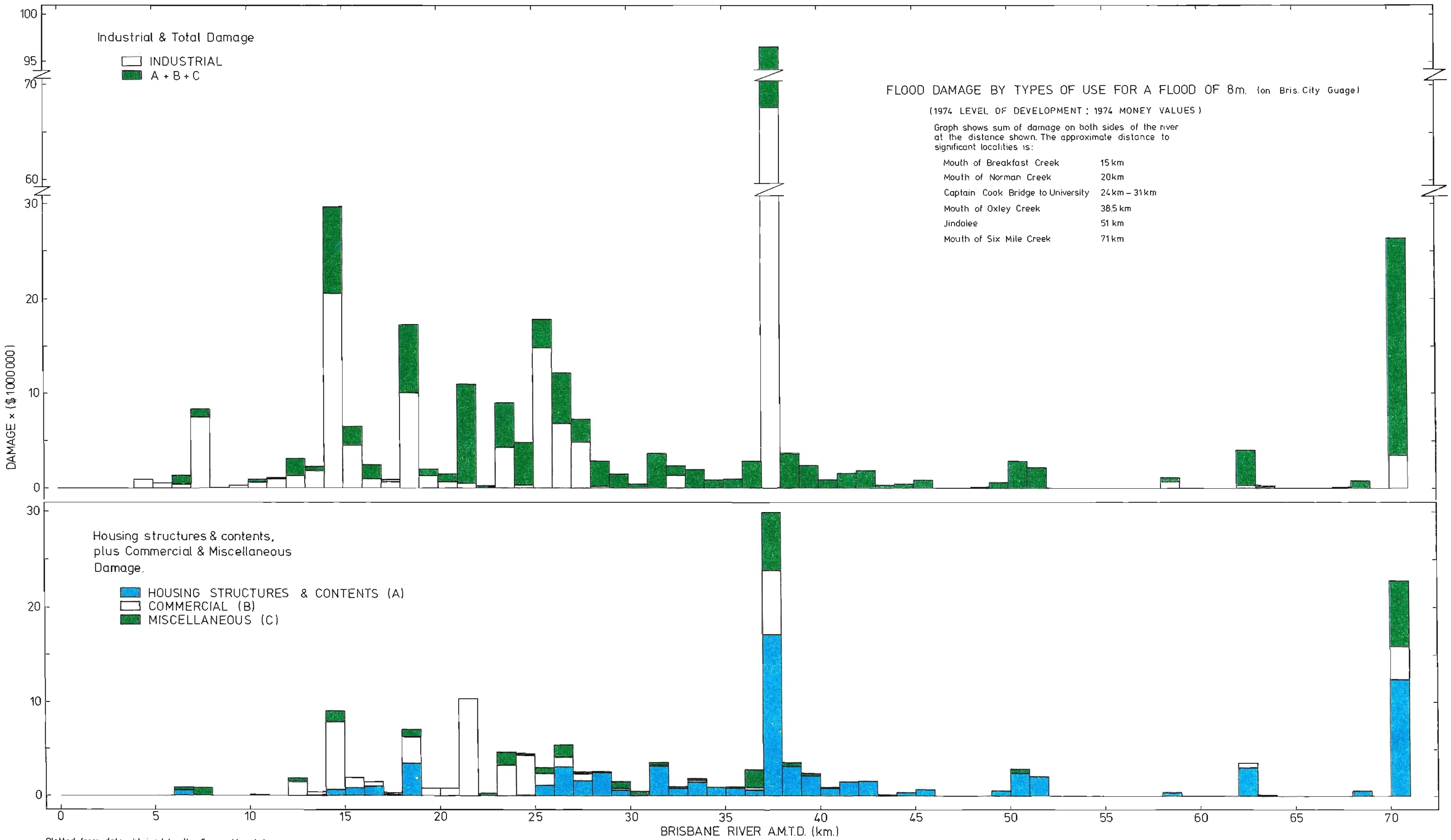
Plotted from data obtained by the Snowy Mountains Engineering Corporation for 'Brisbane River Flood Investigations - Final Report', November, 1975

4m. FLOOD HEIGHT - FIGURE 4



Plotted from data obtained by the Snowy Mountains Engineering Corporation for "Brisbane River Flood Investigations - Final Report", November, 1975.

6m. FLOOD HEIGHT - FIGURE 5



Plotted from data obtained by the Snowy Mountains Engineering Corporation for "Brisbane River Flood Investigations – Final Report", November, 1975

8 m. FLOOD HEIGHT - FIGURE 6

show the variation in damage potential along the river as well as the variation in the various elements that make up total damage. The figures highlight the damage potential in the tributary creek flood plains due to backwater flooding. The Snowy Mountains Engineering Corporation in its report (23) examined damage in the flood plains of the Brisbane River tributary creeks and the likelihood of 'double' flooding, i.e. flooding of the tributary flood plain by the tributary stream followed by backwater flooding from the Brisbane River. The estimated flood damage in the Bremer River flood plain was discounted by 30% to allow for the effect of Bremer River flooding. No discount was applied to estimated damages in the flood plains of tributary creeks.

11.5 FLOOD DAMAGE REDUCTION AND STRUCTURAL MEASURES

Storage reservoirs or other structural measures such as levees, channel improvements, etc., are engineering measures which aim to alter the flood. They are only one of a number of approaches to reducing flood damage.

United States experience (e.g. Kates (29)), suggests that:

(a) average annual flood damages are continuing to increase in almost all flood prone areas despite, in many cases, already large expenditures on structural works;

(b) the potential for major flood damage is increasing because people (that is, firms and households) move into flood plains 'protected' by structural measures (engineering works) apparently believing that the structures will give complete protection; and

(c) people often move into known flood hazard areas fully expecting, and often receiving, 'free' government help such as subsequent structural protection (flood mitigation works) and/or emergency relief in the event of a flood.

Hence in the design of flood mitigation works the likely large movement of activities on to the flood plain, because of an over-optimistic estimate of the flood mitigation potential of the works, should be considered. Means, other than engineering works, which will reduce flood damages, are available if it is accepted that people can adjust to floods. These adjustments may require means to distribute losses (through insurance and relief and rehabilitation schemes) and to change or regulate land usage in flood plain areas (through flood warning systems, flood-proofing of buildings and flood plain zoning, for example). Grigg (30) has discussed the appropriateness of these adjustment measures in coping with the flood hazard and in damage reduction.

The provision of a flood storage in Wivenhoe Dam should not be interpreted as eliminating river flooding in Brisbane City, Ipswich City and Moreton Shire. Complementary measures such as flood plain zoning will be required if the benefits arising as a result of the flood storage are not to be lost by encroachment in the future onto the flood plain. If continuing encroachment onto the flood plain is not restrained, flood damage due to high floods that will still occur will continue to increase.

11.6 COSTS OF WIVENHOE FLOOD STORAGE

The terms - interest rate, discount rate, planning period, present worth, equivalent uniform annual cost (or benefit), risk and uncertainty - used in the analysis are defined in Appendix 6.

The direct costs of providing a flood storage in Wivenhoe Dam over and above that of the proposed urban water supply storage can be divided into dam costs, land acquisition costs and the relocation costs of roads and of services.

The Irrigation and Water Supply Commission estimated in January 1976 (21) that a water supply storage of 1 140 000 Ml (F.S.L. EL 67 AHD and Crest Level EL 79 AHD) would cost a total of $58.78M. The Commission also estimated that the extra costs of providing various flood storages would be as set out in Table 11.4.

TABLE 11.4

FLOOD STORAGE COSTS ($M)

Flood Storage (Ml) Crest Elevation (AHD)	500 000 73	800 000 75	1 100 000 77	1 400 000 79
Cost Item				
Dam	0.62	0.95	2.41	3.86
Land Acquisition	2.40	4.24	6.09	9.52
Relocation - Roads and Services	0.83	1.46	2.09	2.72
TOTAL	3.85	6.65	10.59	16.10

Source: Irrigation and Water Supply Commission (21)

The equivalent uniform annual costs in 1974 money values are as set out in Table 11.5 for a range of discount rates.

TABLE 11.5

EQUIVALENT UNIFORM ANNUAL COSTS ($M) OF FLOOD STORAGES IN 1974 MONEY VALUES

Flood Storage (Ml)	Discount Rate		
	8% p.a.	10% p.a.	12% p.a.
500 000	0.433	0.588	0.770
800 000	0.752	1.023	1.339
1 100 000	1.174	1.590	2.071
1 400 000	1.795	2.431	3.174

11.7 BENEFITS (TOTAL) TO EXISTING DEVELOPMENT

Benefits are defined here as a reduction in damage and the premise is that beneficiaries are prepared to pay the full amount of the reduction to avoid this damage. An analysis, described in Appendix 7, based on the stage damage curve, historic flood heights and estimated frequencies shows that the expected equivalent uniform annual benefits for a range of flood storages with development in the flood plain as at mid 1974, are as set down in Table 11.6 The expected equivalent uniform annual damage in the case of Somerset Dam only has been assessed as $6.18m.

TABLE 11.6

TOTAL EXPECTED EQUIVALENT UNIFORM ANNUAL BENEFITS ($M) Mid 1974 development and money values

Discount Rate 10% - 75 year planning period

Wivenhoe Dam Flood Storage (Ml)	Expected Equivalent Uniform Annual Benefit ($m)	Residual Expected Equivalent Uniform Annual Damage ($m)
None (Somerset Dam only)	0	6.18
500 000	2.78	3.40
800 000	3.91	2.27
1 100 000	4.97	1.21
1 400 000	5.28	0.90

The planning period referred to in the Table is the length of time considered in the economic study and in this case seventy-five years has been used. Project consequences occurring within the planning period are included in the analysis. Consequences occurring later than seventy-five years are not considered. Standard practice in the assessment of water resource projects in the United States is to use periods of between fifty and one hundred years. With the discount rates used in this study, there is little difference in the final results if a length of time anywhere within the range is used.

Expected equivalent uniform annual benefits, using the same analysis, for average growth rates on the flood plain areas of 1%, 2% and 5% per annum and for a range of discount rates, are shown in Table 11.7. Growth rates allow for both the increase in asset value over time for existing development in the flood plain and also for additional development in the flood plain.

TABLE 11.7

TOTAL EXPECTED EQUIVALENT UNIFORM ANNUAL BENEFITS ($M)
Mid 1974 Development + Growth and 1974 money values
75 Year Planning Period

Flood Storage Ml	Discount Rate								
	8% p.a.			10% p.a.			12% p.a.		
	Growth Rate p.a.			Growth Rate p.a.			Growth Rate p.a.		
	1%	2%	5%	1%	2%	5%	1%	2%	5%
500 000	3.20	3.74	6.80	3.12	3.54	5.66	3.06	3.40	4.96
800 000	4.50	5.26	9.65	4.39	4.97	7.96	4.31	4.78	6.98
1 100 000	5.72	6.68	12.26	5.57	6.32	10.12	5.47	6.08	8.88
1 400 000	6.08	7.10	13.03	5.92	6.72	10.75	5.82	6.46	9.43

11.8 OPTIMAL STORAGE - TOTAL BENEFITS - (NO COMPLEMENTARY NON-STRUCTURAL MEASURES)

The optimal size of the storage is defined as that size beyond which the marginal rate of return on investment falls below the discount rate, i.e. the minimum acceptable rate of return. The size of the storage so determined maximises net benefits for that discount rate. Table 11.8 shows optimal storage sizes for various discount rates and growth rates assuming that there are no complementary non-structural measures.

Table 11.8 shows that the result is not very sensitive to the assumptions of either growth rate or discount rate and that a storage in the range of 1 000 000 Ml to 1 300 000 Ml could be justified for 1974 development and money values.

TABLE 11.8

OPTIMAL FLOOD STORAGE SIZE (Ml)
(No complementary non-structural measures)

Discount Rate % p.a.	Growth Rate % p.a.		
	0%	2%	5%
8%	1 100 000	1 175 000	1 290 000
10%	1 090 000	1 160 000	1 260 000
12%	1 050 000	1 100 000	1 150 000

The values of benefits derived in Tables 11.6 and 11.7 are the expected equivalent uniform annual benefits. The actual benefits arising from an investment in a flood storage will vary because of the randomness with which future flooding events will occur, i.e. the risk. Also the analysis only makes use of a limited record of flood events - 89 consecutive years - so no certainty can be attached to the assigned probabilities of occurrence of floods of a certain height. Because of this uncertainty, the expected equivalent uniform annual benefits above could be in error.

The results of a risk and uncertainty analysis - Appendix 7 - are shown in Table 11.9. The Table shows for a 75 year planning period, and a 10% discount rate:

(a) if the flood probabilities are correct, the statistical risk that benefits will be less than costs; and

(b) if the flood probabilities are in error, the chance that benefits will be less than costs.

TABLE 11.9

RISK AND UNCERTAINTY
Discount Rate 10% - 75 year planning period
No Growth - Mid 1974 Development only

Flood Storage (Ml)	Chance that the actual present worth of 'total' benefits $\leq$ present worth of costs	
	For Risk	For Uncertainty
1 100 000	22%	3.5%
1 400 000	35%	15.0%

11.9 CRITICISM OF 'TOTAL BENEFITS' APPROACH

The above analysis is the type often used to evaluate the effectiveness of structural measures of flood mitigation. It fails to take into account the encouragement that flood mitigation works give for continuing encroachment into high flood hazard areas in the absence of controls on flood plain occupation. A flood storage in the Wivenhoe Dam, in the absence of complementary non-structural measures, will encourage further investment in the Brisbane River Flood Plain so that flood damages in the future will rise. The increase in flood damage might be as high as or higher than the claimed benefits. Non-structural measures (land use planning in the flood plain, etc.) in combination with a flood storage will usually give a more effective solution.

An alternative approach to the evaluation will be based on the following considerations:

(a) there are a number of means of coping with flood hazards and achieving flood loss reduction other than by structural measures, (engineering works);

(b) non-structural measures aimed at regulating the occupation of the flood plain in association with the construction of a flood storage will yield greater benefits than a flood storage with no complementary measures;

(c) there are some flood effects that cannot be stated in money terms, e.g. anxiety before, during and after flood and possible loss of life. This raises the question of what is a 'socially acceptable' flood hazard.

11.10 AN ALTERNATIVE ANALYSIS

Occupants of flood plains (both households and firms) appear to be either:

(a) completely unaware of the flood hazard or, if aware that there is a hazard, they are not in a position to understand or evaluate its significance; or

(b) aware that there is a hazard but prepared to gamble on it.

These attitudes tend to be encouraged if the whole community bears the costs of flood mitigation schemes and if only flood plain occupants receive the benefits.

If the community at large has to bear the cost of flood mitigation works then it could be argued that the community has an obligation to ensure that people do not locate in areas of high flood hazard even if they are aware of the hazard and are prepared to accept it. Flood plain zoning is considered to be the most effective way of ensuring that activities are not located in high hazard areas unless they are flood tolerant.

Flood plain zoning is usually based on a flood of a particular probable frequency called the 'regulatory' flood. It is usual to allow no development in the 'floodway' needed to pass the 'regulatory' flood except for public utility crossings, recreation areas, parks etc. The area of the flood plain outside the 'floodway' is called the 'floodway fringe' area and varying parts of this area will be flooded by floods of greater heights than the 'regulatory' flood. Land use zoning of the flood plain based on a 'floodway' and a 'floodway fringe' area will reduce community losses especially if no commercial, industrial or residential activity is allowed in the 'floodway' and if only land uses that are flood tolerant are allowed in the 'floodway fringe'. The 'regulatory' flood is based on the degree of flood hazard acceptable to the community. If a 'socially acceptable' hazard level is defined as that corresponding to a particular probable frequency flood, e.g. 1:30, 1:50, then the residents located below that flood level, flooded above floor level, would be affected more than is 'socially acceptable'. In the United States and the United Kingdom a 'regulatory' flood with a probable frequency of 1:100 is adopted.

Table 11.10 shows the statistical risk of flooding for given probable frequency floods.

TABLE 11.10

RISK OF FLOODING

Probable frequency of flooding	Risk that Intervals between Floods of this Magnitude ≤ Interval Specified			
	50%	25%	10%	5%
1 : 100	69 yrs.	29 yrs.	11 yrs.	5 yrs.
1 : 30	21 yrs.	8 yrs.	4 yrs.	2 yrs.

Thus in any 29 year period there is a 25% risk that one or more floods of magnitude equal to or greater than the 1:100 probable frequency flood will occur. There is a 25% risk that a flood equal to or greater than the 1:30 probable frequency flood will occur in any 8 year period.

An analysis based on a 'regulatory' flood, i.e. a flood of a certain probable frequency, assumes that non-structural measures, e.g. flood plain zoning, sub-division and building regulations, flood proofing requirements, would be implemented and encroachment onto the flood plain would be regulated.

A distinction could then be made between the benefits accruing to the occupiers of flood plain property outside the 'floodway' ('justified' benefits) and those within the 'floodway' ('unjustified' benefits). The optimal flood storage could be determined on the basis of 'justified' benefits and strategies could be devised for dealing with occupiers of property in the 'floodway', i.e. those properties subject to an unacceptable hazard. The costs of dealing with property within the 'floodway' could be viewed as the costs required to correct past errors in land use planning and the cost of ensuring that in the future there would be no encroachment into the 'high hazard' areas. For a more complete discussion of the above see Appendix 7.

A strategy for reducing flood losses in the 'floodway' could be:

(a) reduce the extent of the 'floodway' by increasing the flood storage above the 'justified' optimum;

(b) acquire, over time, residential properties within the 'floodway'. The owners of these properties find it difficult to purchase flood insurance. It should be noted that flood insurance does not reduce the flood loss to the community. Allow commercial and industrial activity to remain since the owners of these activities can generally purchase flood insurance. Rebuilding should not be allowed on the site of commercial and industrial activities and the land only purchased in the future. The optimum 'floodway' clearing strategy would be the minimum cost combination of the above.

The need to empty flood waters stored in Wivenhoe Dam and Somerset Dam as soon as possible to have them in readiness for another flood means that the period of inundation for low levels of the flood plain will be increased. This increase in social cost to residents of the lower levels of the flood plain to provide less flood damage etc. to residents on higher levels is another reason for clearing low lying areas of the flood plain to provide a 'floodway'.

11.11 PROPERTIES AFFECTED BY FLOODING

On the request of the Co-ordinator-General, the Snowy Mountains Engineering Corporation (31) provided details of property damage and of the number of properties affected for the mid 1974 stage of development above certain flood heights. Table 11.11 shows details of the number of buildings affected and the estimated flood damages.

Table 11.12 gives further details of the number of buildings affected for floods below 4.0m on the Brisbane City Gauge assuming the mid 1974 stage of development.

TABLE 11.11

BUILDINGS AFFECTED AND DAMAGE
Mid 1974 stage of development and 1974 money values

Flood Height	Commercial		Industrial		Residential		Miscellaneous		Total Buildings
	No.	Damage ($m)	No.	Damage ($m)	No.	Damage ($m)	No.	Damage ($m)	No.
2m	165	0.07	64	1.07	208	0.20	32	0.40	469
4m	708	6.8	861	27.3	4 941	12.3	206	3.4	6 716
6m	1 230	25.2	2 925	94.4	11 614	44.0	515	12.3	15 284
8m	1 664	47.1	2 615	158.0	18 461	89.5	786	22.7	23 526

Note: Minor Sundry Damages have been omitted.

Source: Snowy Mountains Engineering Corporation (23).

TABLE 11.12

BUILDINGS AFFECTED - LOWER LEVEL FLOODING
Mid 1974 stage of development

Flood Height	Greater than or equal to floor level				Less than Floor Level - Residential	Total Residential
	Commercial	Industrial	Miscellaneous	Residential		
2.0m	7	64	11	42	166	208
2.5m	34	161	35	233	567*	800*
3.0m	79	349	76	706	1 194*	1 900*
3.5m	189	577	130	1 400	2 000*	3 400*

* By interpolation from report (23).

Source: Snowy Mountains Engineering Corporation (31).

The probable frequencies for various flood heights on the Brisbane City Gauge based on the adoption of the Log. Pearson Type III distribution are shown in Table 11.13.

TABLE 11.13

ADOPTED PROBABLE FREQUENCY OF GIVEN BRISBANE RIVER FLOOD HEIGHTS (BEFORE CONSTRUCTION OF WIVENHOE DAM)

Brisbane City Gauge Height (EL AHD)	2.0	2.5	3.0	3.5	4.0	5.5	6.0	8.0
Probable Frequency	1:11	1:14	1:18	1:23	1:28	1:50	1:60	1:110

Source: Snowy Mountains Engineering Corporation (23).

A flood storage built in the Wivenhoe Dam will reduce the number of dwellings below the acceptable hazard level as defined, by lowering the flood height of the particular probable frequency flood on which the level is based. Some areas will still be below the acceptable hazard level regardless of the flood storage size. One option could be to purchase residences below the acceptable hazard level over a period of time.

11.12 POTENTIAL COSTS OF RESIDENTIAL PROPERTY ACQUISITIONS IN HIGH HAZARD AREAS

The Valuer-General's Department (32) at the request of the Co-ordinator-General's Department prepared a schedule of estimated acquisition costs (based on 1976 current market values) for residences affected by floods up to the 2 metres height and by floods between the 2 metres and 4 metres height on the Brisbane City Gauge. The estimated average market value for the residences was $20 246 for properties below the 2 metre level and $24 504 for properties between the 2 metre and 4 metre levels. The Valuer-General noted that:

> "Sales evidence relating to properties inundated in the (January) 1974 flood indicates that, with the passage of time less buyer-resistance is being encountered in flood prone areas and values of properties within these areas, which were depressed by the 1974 flood, are returning quickly to a level of value nearly comparable with properties which are unaffected by flooding."

In the analysis an average figure of $30 000 per developed site has been used. The reasons for using a higher value than the average values stated above are:

(a) some allowance should be made for the costs incurred by the responsible authorities to map accurately areas to be acquired and to administer the acquisition procedures;

(b) the number of properties not built upon which would be affected is not accurately known and an allowance should be made for the cost of acquisition of these properties;

(c) it is likely that final acquisition payments will be somewhat higher than the stated market value to compensate owners for having to move to an area less attractive to them.

11.13 COMBINED FLOOD STORAGE AND FLOODWAY CLEARANCE EVALUATION

The approach adopted - see Appendix 7 - was to consider various flood storage volumes and a wide range of 'socially acceptable' hazard levels ranging from 1:20

to the 1:100 probable frequency flood levels. Within the range of hazard levels, two cases of clearing residential properties within the floodway over time were considered:

(a) only properties affected above the floor level; and

(b) all properties affected - both above and below floor levels.

It was assumed that acquisition would proceed over an extended period of time. Owners would be able to stay in their residences for as long as they wished, but when they wished to move, their residences would be acquired. For analysis purposes it was assumed that acquisition of the properties flooded above floor level would be completed between 1981 and 1991 while properties flooded below floor level would be acquired over a period of twenty-five years from 1981.

Table 11.14 shows the storage volume required for a number of hazard levels for the two floodway clearance strategies. As the 'socially acceptable' hazard level becomes lower, the required flood storage volume increases for the same discount rate. Volumes tend, in general, to decrease with increases in the discount rate. The assumptions about growth rate are of little significance.

TABLE 11.14

FLOOD STORAGE CAPACITIES 1000 Ml - COMBINED STORAGE AND FLOODWAY CLEARANCE

Socially Acceptable Hazard - Probable Frequency Flood	Growth Rate % p.a.	Discount Rate					
		8% p.a.		10% p.a.		12% p.a.	
		Above Floor[1]	All[2]	Above Floor	All	Above Floor	All
1 : 100	0%	1 200	1 400	1 120	1 300	1 075	1 300
	5%	1 240	1 450	1 140	1 350	1 090	1 300
1 : 50	0%	1 100	1 300	1 080	1 200	1 000	1 150
	5%	1 230	1 325	1 140	1 225	1 120	1 190
1 : 30	0%	1 080	1 150	1 045	1 050	920	1 050
	5%	1 210	1 210	1 160	1 160	1 130	1 130
1 : 20	0%	1 100	1 100	1 050	1 050	1 040	1 040
	5%	1 190	1 190	1 180	1 180	1 130	1 130

1. Acquisition of residential properties flooded above floor level by the flood of specified probable frequency.

2. All residential properties below the acceptable hazard level acquired.

Table 11.15 shows suggested flood storages based on benefits accruing only to those properties above acceptable hazard level. These storages can be compared with those in Table 11.14.

TABLE 11.15

FLOOD STORAGE CAPACITIES (Ml) BASED ON BENEFITS ONLY TO DEVELOPMENT ABOVE ACCEPTABLE HAZARD LEVEL

Socially Acceptable Hazard - Probable Frequency Flood	Growth Rate % p.a.	Discount Rate 8% p.a.	10% p.a.	12% p.a.
1 : 100	0%	980 000	500 000	0
	5%	1 240 000	1 140 000	1 090 000
1 : 50	0%	1 050 000	1 040 000	570 000
	5%	1 230 000	1 140 000	1 120 000
1 : 30	0%	1 080 000	1 045 000	920 000
	5%	1 210 000	1 160 000	1 130 000
1 : 20	0%	1 100 000	1 050 000	1 040 000
	5%	1 190 000	1 180 000	1 130 000

For high hazard levels, i.e. 1:20, 1:30, there is essentially no difference in the results, because of the relatively small number of residences below the hazard level. For lower hazard levels the difference is minimal if the high growth rate is assumed. In all cases, the storage size justified is slightly less than those shown in Table 11.14. A comparison of Tables 11.14 and 11.15 shows that, in general, large increases in the flood storage size in an attempt to avoid 'floodway' clearance cannot be justified.

Table 11.16 shows the acquisition limits, for the various cases considered in Table 11.14, that should be adopted for 'floodway' clearance. The acquisition or 'floodway' limits are defined by the flood envelope of the 'regulatory' flood. The acquisition limits are most easily described in terms of the corresponding flood height on the Brisbane City Gauge of the flood of 'socially acceptable' hazard.

The choice of a 1:100 probable frequency flood as the acceptable hazard level implies an acquisition limit somewhere between 3.20m and 3.40m on the Brisbane City Gauge if only residential properties flooded above floor level are acquired and between 3.05m and 3.15m on the Brisbane City Gauge if all residential properties below the hazard level are acquired. The results of the analyses presented in Tables 11.14 and 11.16 are summarised in Table 11.17. The 'only above floor level' case might not be practicable although the acquisition of such properties should receive priority.

TABLE 11.16

ACQUISITION LIMITS - FLOODWAY CLEARANCE

Socially Acceptable Hazard - Probable Frequency Flood	Growth Rate % p.a.	Acquisition limits corresponding to flood heights on Brisbane City Gauge (EL AHD)					
		Discount Rate					
		8% p.a.		10% p.a.		12% p.a.	
		Above Floor	All	Above Floor	All	Above Floor	All
1 : 100	0%	3.25	3.10	3.35	3.15	3.40	3.15
	5%	3.20	3.05	3.30	3.10	3.35	3.15
1 : 50	0%	2.80	2.65	2.80	2.70	2.95	2.75
	5%	2.70	2.60	2.75	2.70	2.80	2.70
1 : 30	0%	2.00	1.95	2.05	2.05	2.25	2.05
	5%	1.95	1.95	1.95	1.95	2.00	2.00
1 : 20	0%	1.20	1.20	1.25	1.25	1.25	1.25
	5%	1.20	1.20	1.20	1.20	1.20	1.20

TABLE 11.17

ACQUISITION LIMITS, PROPERTIES TO BE ACQUIRED AND FLOOD STORAGE FOR VARIOUS HAZARD LEVELS

Socially Acceptable Hazard Level - Probable Frequency Flood	Case	Range of			
		Acquisition Limit - Gauge Height on Brisbane City Gauge	Properties to be acquired (Approx.)	Flood Storage (000 Ml)	Expected Residual Equivalent Uniform Annual Residential Damage ($m)
1 : 100	A.F.*	3.20-3.40	900-1240	1075-1240	v. small
	All	3.05-3.15	2020-2290	1300-1450	v.small
1 : 50	A.F.	2.70-2.95	400- 650	1000-1230	0.07
	All	2.60-2.75	980-1290	1150-1325	0.05
1 : 30	A.F.	1.95-2.25	35- 105	920-1210	0.14
	All	1.95-2.05	175- 240	1050-1210	0.13
1 : 20	A.F. & All	1.20-1.25	0	1040-1190	0.14
No floodway clearance	A.F. & All	None	0	1050-1290	0.14

* A.F. Above floor.

Table 11.17 shows the range of acquisition limits for various hazard levels, the estimated number of residences that would need to be acquired and the range of flood storage volumes. The Table also shows that for the range of discount rates and growth rates considered flood storage sizes do not vary greatly. It shows also that, in the case of no floodway clearance, the expected residual equivalent uniform annual residential damage is $0.14M. As 'socially acceptable' hazard decreases, the level of residual damages increases.

Table 11.18 shows the benefits and costs and total damage reduction for the case of zero growth and the acquisition of residences flooded above the floor level for various discount rates and acceptable hazard levels for the mid 1974 stage of development.

TABLE 11.18

COSTS AND BENEFITS - (ZERO GROWTH)
FLOOD STORAGE PLUS FLOODWAY CLEARANCE

(Residences flooded above floor level acquired only)
Mid 1974 stage of development - zero growth

Discount Rate (% p.a.)	'Socially Acceptable' Hazard Level	Costs		Expected Equivalent Uniform Annual Justified Benefits ($m)	Total expected damage reduction and damage avoided by floodway clearance (Equivalent Uniform Annual) ($m)
		Equivalent Uniform Annual Costs ($m)	Present Worth ($m)		
8%	None	1.20	15.0	5.00	5.00
	1 : 20	1.20	15.0	4.20	4.95
	1 : 30	1.23	15.4	3.20	4.90
	1 : 50	1.92	24.0	2.25	4.95
	1 : 100	3.04	38.0	1.40	5.35
10%	None	1.55	15.5	4.95	4.95
	1 : 20	1.50	15.0	4.10	5.10
	1 : 30	1.55	15.5	3.15	5.10
	1 : 50	2.31	23.1	2.15	5.10
	1 : 100	3.74	37.4	0.70	5.10
12%	None	1.95	16.3	4.85	4.85
	1 : 20	1.90	15.8	4.05	4.80
	1 : 30	1.84	15.3	2.85	4.35
	1 : 50	3.09	25.8	1.35	4.65
	1 : 100	4.42	36.8	0	4.90

The costs of implementing a combined flood storage/floodway clearance strategy below levels of 'socially acceptable' hazard are higher than in the case of the purely structural approach where no 'socially acceptable' hazard level would be defined. The structural approach, without complementary non-structural measures, encourages encroachment onto the flood plain. The social problem of fairly frequent flooding of residences in low levels of the flood plain is made worse if encroachment is allowed.

The above analysis has ignored uncertainty in relation to the peak flood levels associated with given probable frequency floods. Uncertainty is defined in Appendix 6. Errors in peak flood levels due to uncertainty, for floods of high probable frequency, e.g. 1:20 and 1:30 probable frequency floods, are considered to be within $\pm$ 0.5m while the error due to uncertainty for floods of low probable frequency, e.g. 1:50 and 1:100 probable frequency floods, could be as high as $\pm$ 2m. In the case of a low probable frequency flood adopted as that of 'acceptable' hazard, measures such as flood insurance should be relied upon to cope with uncertainty for properties located above the acquisition limit in floodway fringe areas.

It should be recognised that there is uncertainty in the estimates of flood damages and construction cost estimates as well as in the hydrologic data. Uncertainty in estimates of flood damages and construction costs have an influence on the acquisition limit and on the flood storage size recommended. Uncertainty in these two areas suggests that there should be marginal increases in acquisition limits and/or flood storage. The least costly and least disruptive approach would be to increase the flood storage. An increase in flood storage should also be made to allow for human errors in interpretation of flood events and for malfunction of equipment in the Dam during flooding events.

11.14 OTHER CONSIDERATIONS

The above discussion only considers flood storage (structural measures) and flood plain zoning and regulation as flood hazard and flood damage reduction measures. Other non-structural measures such as flood insurance, flood warning and evacuation systems, relief and rehabilitation programmes and the flood proofing of existing and new buildings can be used in association with flood plain zoning but they do not provide a complete alternative to structural measures.

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Unlike structural measures, non-structural measures require general community acceptance for their success. Their continued success is in jeopardy if long time intervals occur between floods because developers exert pressures to be allowed to encroach into the flood hazard areas and the residents of the flood prone area are likely to lapse into a state of unpreparedness with respect to individual flood loss reduction measures.

There is a need for the public to be informed about how to interpret flood warnings, how to formulate flood emergency plans, how to flood proof buildings and how to use Flood Plain Maps such as those issued in 1976 for the Brisbane and Bremer Rivers.

Flood insurance is widely held to be a satisfactory way to deal with flood losses. If the premiums correctly reflect the hazard, then the insured pays for his own loss. If the premiums underestimate the hazard, i.e. are too low, then other insured persons or the community, in the case of a subsidised flood insurance scheme, bear some of the loss. Flood insurance does not reduce either the material loss or the social trauma arising from floods. A flood insurance scheme, where premiums are based on the flood hazard such as the United States scheme, brings the flood hazard to the notice of those intending to build or purchase dwellings in the flood plain.

The United States flood insurance scheme makes flood insurance available to residences and small businesses in communities that adopt flood plain management measures, e.g. flood plain zoning, based on the 'regulatory' flood laid down in the National Flood Insurance Act of 1968 and subsequent amendments. Owners of residences and small businesses already located in the flood plain at the time the community comes under the provisions of the Act can have their premiums subsidised. Owners who move into the flood plain after the community comes under the provisions of the Act are not subsidised. If flood insurance is subsidised the community shares some of the costs of flood losses of owners located in the flood plain while the owners continue to receive the benefits of their location in the flood plain. Many existing owners may be located in the flood plain unwittingly and it could be argued that some subsidy is justified, but after the flood plain is zoned, new development in the flood plain should not receive subsidised flood insurance. Unsubsidised flood insurance is useful in providing loss cover for the residual flood damage after structural measures have been built.

Flood losses due to floods in the Bremer and Brisbane Rivers can best be reduced now by a combination of constructing a flood storage in Wivenhoe Dam, by clearing the flood plain to a certain level to provide a 'floodway' and by flood plain zoning and controls to ensure that the benefits of the flood storage and 'floodway' clearance are not lost over time by encroachment on to the flood plain.

SECTION 12

ALLOCATION AND SHARING OF PROJECT COSTS

12.1 SYNOPSIS

The justification for the project should be based on economic, social and environmental considerations. There is also a need to consider the financial implications with respect to the availability of funds. Since the project is a multi-purpose facility, the allocation of costs between the different purposes should be examined. Once the cost allocation for a particular purpose has been determined, there is still the problem of sharing that cost between the various instrumentalities and the different levels of Government using that service.

Many decisions had already been made on cost allocations prior to this study. The broad issues will be discussed and an effort will be made to establish reasonable principles to guide cost allocation and cost sharing for future multi-purpose dams.

12.2 PROJECT PURPOSES AND COST ALLOCATION

The proposed Wivenhoe Dam will be a multi-purpose facility. It will augment urban water supply, provide substantial flood mitigation and serve as the lower pool for a pumped storage hydro-electric scheme. It will also have a recreation potential and in the future it might provide the boiler feed and cooling water required for a large thermal power station. The primary purposes for which the Dam will be built are urban water supply and flood mitigation and its use for these purposes means that it will be available as a lower storage for the pumped storage hydro-electric scheme. If the urban water supply augmentation had been developed elsewhere then:

(a) the peak electricity power needs in the 1980's would have had to be supplied by a pumped storage scheme at another site or by a new peak load thermal station; and

(b) at some time present or future further structural measures to mitigate floods in the Brisbane River would have been necessary.

The decision to build the Dam was taken on the basis that not only was the cost per unit of urban water cheaper than at the best alternative site, but that substantial flood mitigation for the lower Brisbane River Valley could be obtained reasonably cheaply.

How much should each purpose contribute to the total project cost?

These three purposes, i.e. urban water supply and recreation, flood mitigation, and power generation will be considered. No decision on the location of the future thermal power station is likely for some considerable time. Urban water supply and recreation have been linked together for convenience as the extent of recreation will be determined by considerations of water quality.

The proposal adopted for analysis is:

(a) 1 140 000 megalitres of storage for urban water supply with an assessed yield of 230 000 megalitres per annum (with 90 per cent confidence of a 1 per cent risk of depletion);

(b) 1 400 000 megalitres of storage for flood mitigation; and

(c) a pumped storage hydro-electric scheme requiring 11 000 megalitres of water daily on average, with a maximum short term requirement of 23 000 megalitres per day. This water would be returned to the Dam with only minor evaporative losses. The minimum water level in the storage necessary for the operation of the scheme is EL 49 AHD.

The allocation of costs need not be based on the order in which a particular purpose is added to the project and then allocating costs on an incremental basis. Another approach could be that each purpose should contribute to the total cost on the basis of the proportion of the value of 'output' used by each purpose modified by the 'savings' accruing to the purpose due to the multi-purpose development. See James and Lee (33).

Information on separable and non-separable costs, alternate costs and/or benefits for each project purpose is required before an allocation based on 'output' can be made. Direct costs attributable to a particular purpose, e.g. the cost of the upper level pond for the pumped storage hydro-electric scheme, will not be considered.

The total Dam cost for three interest rates for this particular proposal is set out in Table 12.1. The amounts represent present worths at 1982, in 1975 money values, i.e. they include capitalised interest to 1982.

TABLE 12.1

TOTAL COST AND COSTS BY PROJECT PURPOSE ($M) - 1981/82
1975 money values
(Wivenhoe Dam only)

Cost Item	Present Worths in 1982 - $M Interest Rate % p.a. 8%	10%	12%
1.*Total Cost (includes capitalised interest)	95.82	101.61	108.28
2. Cost excluding Flood Mitigation	73.38	77.30	81.83
3. Cost excluding Urban Water Supply i.e. cost of 1 625 000 megalitres storage capacity	78.38	82.80	88.08
4. Separable Costs:			
Pumped Storage Hydro-electric scheme	0	0	0
Urban Water Supply	17.44	18.81	20.20
Flood Mitigation	22.44	24.31	26.45
Total	39.88	43.12	46.65
5. Non-Separable Costs	55.94	58.49	61.63

* assumes no extra cost to the Dam on account of its use as a lower storage for the pumped storage hydro-electric scheme.

The costs of a scheme which excluded an urban water storage have been based on a storage of 1 625 000 megalitres comprising a storage volume of 225 000 megalitres for the pumped storage hydro-electric scheme and 1 400 000 megalitres left empty for flood storage. The storage for the pumped storage hydro-electric scheme corresponds with one with a minimum stored water level of EL 49 AHD together with a full supply level of EL 53 AHD sufficient to yield 25 000 megalitres per annum at 1 per cent risk of depletion (with 90 per cent confidence). See Table 10.4.

The total non-separable costs are about 60 per cent of total costs. The problem is to allocate these non-separable costs between the various project purposes on an equitable basis. Possible cost allocations will be based on:

(a) quantity of use;

(b) excess costs (the total costs at the next best alternative site for that purpose less the costs separable to that purpose);

(c) excess benefits (the total purpose benefits less the costs separable to that purpose);

(d) minimum of (b) or (c).

TABLE 12.2

COST ALLOCATION (PRESENT WORTH $M) VARIOUS ALLOCATION METHODS
(Wivenhoe Dam Only)

Allocation Method	8% p.a.				10% p.a.				12% p.a.			
	Power	Water	Flood	Total	Power	Water	Flood	Total	Power	Water	Flood	Total
Separable costs	0	17.44	22.44	39.88	0	18.81	24.31	43.12	0	20.20	26.45	46.65
Quantity of Use:												
Storage in Ml x 10^6	0.10	1.14	1.40	2.64	0.10	1.14	1.40	2.64	0.10	1.14	1.40	2.64
Non-Separable Costs ($M)	2.12	24.16	29.66	55.94	2.21	25.26	31.02	58.49	2.33	26.61	32.69	61.63
Total Costs to each purpose ($M)	2.12	41.60	52.10	95.82	2.21	44.07	55.33	101.61	2.33	46.81	59.14	108.28
Excess Costs:												
Alternate Costs ($M)	11.40	73.38	88.75	173.53	12.00	77.30	67.20	156.50	12.70	81.83	49.69	144.22
Excess Costs ($M)	11.40	55.94	66.31	133.65	12.00	58.49	42.89	113.38	12.70	61.63	23.24	97.57
Non-Separable Costs ($M)	4.77	23.41	27.76	55.94	6.19	30.17	22.13	58.49	8.02	38.93	14.68	61.63
Total Costs to each purpose ($M)	4.77	40.85	50.20	95.82	6.19	48.98	46.44	101.61	8.02	59.13	41.13	108.28
Excess Benefits: (In this case excess benefits to water assumed high enough to allocate all non-separable costs to water.)												
Benefits ($M)	18.00	n.s.	88.75	v.high	18.00	n.s.	67.20	v.high	18.00	n.s.	49.69	v.high
Excess Benefits ($M)	18.00	v.high	66.31	v.high	18.00	v.high	42.89	v.high	18.00	v.high	23.24	v.high
Non-Separable Costs ($M)	0	55.94	0	55.94	0	58.49	0	58.49	0	61.63	0	61.63
Total Costs to each purpose ($M)	0	73.38	22.44	95.82	0	77.30	24.31	101.61	0	81.83	26.45	108.28
Minimum of Excess Costs/ Excess Benefits:												
Excess Benefits ($M)	18.00	n.s.	88.75	v.high	18.00	n.s.	67.20	v.high	18.00	n.s.	49.69	v.high
Alternate Costs ($M)	11.40	73.38	88.75	173.53	12.00	77.30	67.20	156.50	12.70	81.83	49.69	144.22
Minimum Excess ($M)	11.40	55.94	66.31	133.65	12.00	58.49	42.89	113.38	12.70	61.63	23.24	97.57
Non-Separable Costs ($M)	4.77	23.41	27.76	55.94	6.19	30.17	22.13	58.49	8.02	38.93	14.68	61.63
Total Costs to each purpose ($M)	4.77	40.85	50.20	95.82	6.19	48.98	46.44	101.61	8.02	59.13	41.13	108.28

Note: n.s. = not specified.

The costs allocated to each purpose then equal the sum of the allocated non-separable costs plus the separable costs for that purpose. See Table 12.2 (p. 109) for the results of the various allocation methods.

The quantity of use method of allocation requires a common unit of usage for each purpose and the only appropriate measure is the volume of storage. The non-separable costs are allocated to each purpose on the basis of the volume of storage used by each purpose. This method does not take into account the savings to each purpose resulting from multi-purpose development.

The excess costs method of allocation considers the costs of the next best alternative site. The purpose separable costs are subtracted from the cost of the next best alternative and the non-separable costs are allocated on the basis of these excess costs. Non-separable costs and separable costs for each purpose are then added to obtain total costs for each purpose.

The proposed Wolffdene Dam on the Albert River is considered to be the best urban water supply alternative to the Wivenhoe Dam. Wolffdene Dam is estimated to have a yield of about two-thirds of the yield of Wivenhoe Dam and the Brisbane City Council (6) and the Co-ordinator-General's Department (4) estimate that the delivered unit costs from Wolffdene Dam would be about the same as those from Wivenhoe Dam if the latter were developed only for urban water supply. The alternative cost is assumed to be the same cost as a water supply dam at Wivenhoe, i.e. $73.38M, $77.30M and $81.83M for the respective interest rates of 8%, 10% and 12%. So as to be able to consider the pumped storage hydro-electric scheme the additional cost of development at an alternative site has been estimated at $11.40M, $12.00M and $12.70M for interest rates of 8%, 10% and 12% respectively.

In the case of flood mitigation the alternative cost has been taken to be the cost of the next best alternative yielding the same economic benefit as a 1 400 000 megalitres storage. The alternative cost has been assumed to be the value of the present worth of all flood premiums on the basis that all affected properties in the Local Authorities of Brisbane City, Ipswich City, and Moreton Shire are insured. The present worth of premiums is assumed to be equal to the present worth of flood damage likely to arise without the Dam and this is calculated to be $88.75M, $67.20M and $49.69M for 8%, 10% and 12% interest rates respectively. It should be appreciated that the above does not assume that a flood storage of 1 400 000 megalitres will mitigate floods to the extent that there will be no damage in the future.

This method of allocation does not take into account the savings to each purpose because of joint development and, in particular, it does not take into account the benefits accruing to each purpose.

The 'excess benefits' method of allocation cannot be developed in the absence of a 'demand management' policy for urban water supply, since the various sectors of the community, in the absence of 'demand management', have not been able to indicate via the pricing mechanism the value each sector places on urban water. When the supply from surface water sources available to the Region have been utilised at some time in the future, restrictions on water use will most likely be applied to ensure supply to essential purposes. The allocation by 'excess benefits' might therefore be considered as an allocation to the highest valued use - in this case urban water supply. Benefits to urban water supply are not estimated and the excess benefits are considered to be very high so that all non-separable costs are allocated to urban water supply. The Pumped Storage Hydro-electric Scheme savings, i.e. 'benefits', have never been stated by the State Electricity Commission(8) other than in qualitative terms and for this analysis they have been assumed as $18m. Total costs for each purpose are found by adding separable and non-separable costs.

This method of allocation ignores the alternative costs which would arise from the next best development for each purpose.

The United States Water Resources Council (34) prefers a method of allocation which uses the minimum of 'excess costs' and 'excess benefits'. Because due account is given to both the benefits and the alternative costs of each purpose in the project, it overcomes the objection to the 'excess benefits' or 'excess costs' methods. For this particular proposal the minimum excess in all cases arises from the 'excess costs' approach and therefore the results will be the same as in the 'excess costs' approach. Non-separable costs are allocated on the basis of the minimum of excess costs and the separable costs for each purpose are added to the non-separable costs to get total costs for each purpose. In the case of a 10 per cent per annum interest rate, this method allocates total costs on the basis of about 6 per cent to power, 48 per cent to urban water supply and 46 per cent to flood mitigation.

Quite different allocations of costs could result if a different allocation method was used. As an example the decision to allocate none of the costs of Wivenhoe Dam to the Pumped Storage Hydro-electric Scheme was taken on the grounds that the Dam was needed for water supply and flood mitigation and the incremental cost of using it for peak power generation was negligible. There is no 'correct' solution, but allocations of costs to the different purposes for which a multi-purpose dam will be used should, it is suggested, consider the costs of alternative development for that purpose and the benefits accruing to that purpose from joint use.

12.3 COST SHARING

The term 'cost sharing' refers to the way in which the cost allocated to a particular project purpose is apportioned between the instrumentalities and levels of Government using the service provided by that purpose.

Any costs allocated to power supply, in the case of Wivenhoe Dam, should be borne by the Electricity Industry since there is only the one instrumentality involved. Under existing arrangements, the costs of urban water supply are shared by the Local Authority (in this case the Brisbane City Council) and the Queensland State Government through its subsidy to water supply schemes. In the case of flood mitigation, there has been, in a few cases in Queensland in the past, a sharing of costs between the Commonwealth, the State Government and the Local Authority. Where the cost sharing for flood mitigation involves only the Queensland Government and the Local Authority there is an agreed subsidy rate paid by the State.

Cost sharing in the case of flood mitigation needs some further consideration. In Section 11, flood mitigation benefits and costs were divided into two categories based on a 'regulatory' flood determined by the level of 'socially acceptable' hazard. These categories are the benefits and costs incurred in dealing with properties below the 'regulatory' flood level and the benefits and costs accruing to the properties above the 'regulatory' flood level.

The costs of dealing with properties below the 'regulatory' flood level, i.e. floodway clearance, depend on the choice of a 'socially acceptable' hazard level. Whether the two categories of the cost of flood mitigation should be considered separately in determining a cost sharing arrangement would depend on whether the different levels of Government consider that these cost categories serve different community objectives, e.g. economic efficiency and social wellbeing.

12.4 CONCLUSIONS

Before this study was completed, a decision had already been made to allocate all non-separable costs to urban water supply - the highest priority use. Arguments in support of this proposition include, for example, in the case of the Pumped Storage Hydro-electric proposal (4), (35):

"No allowance has been included in the estimate for a contribution to the cost of the main Wivenhoe water supply and flood mitigation dam. The pumped storage scheme need not increase the cost of the Wivenhoe storage nor reduce its yield."

The analysis above indicates that there might be other ways of considering cost allocation than on the basis of whether the added purpose increases the cost of the dam built for the primary purpose. While the analysis is based on insufficient data it gives some idea of likely outcomes. In the case of Wivenhoe Dam it was originally approved as a water supply and flood mitigation structure and a power generation purpose was added later. Each purpose was analysed separately and incremental costs identified. In future multi-purpose projects all the purposes for which the dam is to be used should be identified and costs should be allocated on the basis of one of the methods set out above. The cost allocation finally agreed upon determines the amount that has to be contributed by each purpose and hence the share that has to be contributed by each user of the service of that purpose and hence the funding of the project.

APPENDIX 1

REPORT ON GEOLOGICAL ASPECTS OF WIVENHOE DAM CATCHMENT BY GEOLOGICAL SURVEY OF QUEENSLAND (1975)

RESUMÉ OF CURRENT KNOWLEDGE

Physiography

The ponded area and immediate surrounds of the proposed dam are situated in the gently undulating, subdued topography of the Brisbane Valley. In the north of the ponded area, slightly more rugged country occurs to the west of Somerset Dam, while two isolated groups of rocky hills formed by resistant rocks occur east of Esk and near Crossdale. East of the proposed reservoir the rugged hills of the D'Aguilar Range form a discrete block of high country limiting the eastern edge of the valley. Much of the area to be inundated is formed by a series of alluvial terraces, which extend for considerable distances from the present river channel.

Geology

The geology of the Brisbane Valley is shown on the Ipswich 1:250 000 Geological Sheet, and is currently being re-mapped at 1:100 000 scale by the Geological Survey. The oldest rocks of the region are the possibly Carboniferous Neranleigh-Fernvale Beds, composed of argillite, greywacke, volcanics, and chert, which form the rugged country of the D'Aguilar Range. On their western margin they are flanked by a fault-bounded wedge of Permian sediments and volcanics (Northbrook Beds). A large dolerite dyke of upper Permian age intrudes the Northbrook Beds near Dundas.

West of the mountainous country formed by these older rocks, sedimentary and volcanic rocks of the Toogoolawah Group, laid down in the structurally controlled Esk Trough in lower to middle Triassic times, outcrop over much of the length of the Brisbane Valley. The Toogoolawah Group is divided into the Bryden Formation, consisting of conglomerate, sandstone and shale, the Neara Volcanics, composed of andesitic boulder beds with some flows and tuffs, and the Esk Formation, made up of conglomerate, sandstone, shale and acid volcanics. This sequence has been folded into a number of north-trending anticlines and synclines. West of Somerset Dam, the Neara Volcanics are intruded by a body of gabbro and granophyre (Somerset Dam Igneous Complex) of Triassic age.

In the south, near the damsite, the Toogoolawah Group rocks are overlain by Triassic to Jurassic sediments (largely sandstones) of the Woogaroo Sub-Group and Marburg Formation, which were laid down in the Moreton Basin. East of Esk and near Crossdale the rocks of the Toogoolawah Group have been intruded by two bodies of rhyolite and trachyte of Tertiary age which have resisted erosion to form prominent hills (e.g. Mount Esk).

In many areas throughout the valley a thin veneer of gravels is present capping hill tops and slopes; these are thought to be remnants of discontinuous deposits of terrestrial gravels of Tertiary age.

The geological history of the Cainozoic alluvial deposits along the Brisbane River is not known in detail, but one possible sequence of events is given by Warner (1967):

(a) Incision of the old Brisbane River to base level and lateral erosion of a broad valley over a long period of time.

(b) Deposition of a predominantly fine-grained alluvium in a low-energy river or lake environment.

(c) Rapid down-cutting of the river and erosion of this alluvium and incision of the stream into bedrock.

(d) Deposition of younger alluvium in a high-energy river environment, which was characteristically coarse-grained with gravel at its base.

(e) Successive further lowering of base levels causing the erosion of the younger alluvium in stages to produce a number of terraces (two or possibly three).

The reservoir area will be located on rocks of the Toogoolawah Group and on the alluvial terraces. The damsite is situated on massive, thick-bedded, medium and coarse-grained sandstone of the Woogaroo Sub-Group (formerly termed the Wivenhoe Sandstone), which is covered close to the river by alluvium in several terraces. Rare, very thin lenses of coal, shale and mudstone are interbedded with the sandstone. The sandstone in the west of the site area is underlain by conglomerate, which is thought to belong to the older, underlying Esk formation. The geology of the site has been described from reconnaissance drilling by Warner (1967) and Zahawi (1970).

Mineral Resources

No mineral deposits are known in the submerged area.

The following mineral occurrences are situated in the catchment area.

Antimony. The Eskdale antimony mine is located 28 km north-west of Esk in the Eskdale Granodiorite. In the narrow fissure lode, stibnite is the dominant mineral with minor silver and arsenic (Denmead 1941, Krosch 1973).

Chromite. In the Neranleigh-Fernvale Beds west of the dam a body of serpentinite with minor chromite outcrops on portion 77, Parish of Dundas.

Gold. Gold associated with pyrite and some arsenopyrite occurs in the Maronghi Creek Beds at Opossum Creek 8 km southeast of Blackbutt(Denmead, 1939), and at Water Gully and Nukinenda Creek south and southeast of Mt. Langan south of Blackbutt (Brooks, 1970).

Magnetite and Ilmenite. These minerals occur in gabbro of the Somerset Dam Igneous Complex of Triassic age (Mathison, 1967). Streams draining this area flow into the Stanley River downstream of Somerset Dam.

Manganese. To the southeast of the dam on portion 38c, Parish of Burnett, a small residual deposit of manganese occurs as stains on joint planes (Brooks, 1957). This is only a minor deposit but appreciable amounts of manganese can be expected to occur throughout the Neranleigh-Fernvale Beds.

In 1969, C.R.A. Exploration Pty. Ltd. as holders of Authority to Prospect 462M carried out geochemical exploration of an area extending from Nanango to Mt. Perseverance passing west of Toogoolawah and Esk (Witcher et al., 1969). Throughout the entire A. to P. manganese in stream sediment samples commonly ranged up to 1000 ppm with some values up to 3000 ppm. The form of the manganese is not known.

Mercury. Minor cinnabar is reported to occur on Browns Creek in State Forest 480 on the Kilcoy-Monsildale Road in rocks of the Toogoolawah Group.

Molybdenum. At Anduramba, 30 km northwest of Esk, a bulk low-grade molybdenum deposit of the porphyry type contains in addition to molybdenite,minor wolframite, pyrite, chalcopyrite and arsenopyrite (Denmead 1935, Witcher et al., 1969).

Nickel. Stream sediment geochemistry anomalies with greater than 100 ppm nickel were located in the region of the chromite deposit (Smith, 1969). A further anomaly to the north is associated with a fault breccia (Hutton, pers. comm.) between the Neranleigh-Fernvale Beds and the Toogoolawah Group south of Varleys Hill. Weber (1968) located a serpentinite body containing 0.4% Ni about 1.6 km north of Northbrook.

Copper, lead, zinc, silver. In the Mount Tin Tin - Mount Deongwar area, 15 km northwest of Esk, a number of small copper lead zinc deposits are located in the Cressbrook Creek Group. The mineralisation is restricted to shear zones in rhyolites, andesites and sediments (Jackson, 1901; O'Connell, 1969, 1970).

Bismuth, gold, silver, lead and zinc. Several deposits are located in the Emu Creek - Mt. Langan area, 17 km south of Blackbutt, on the northern margin of the Eskdale Granodiorite and in the Maronghi Creek Beds. Some arsenic is reported to occur in the area (Ball, 1906, 1920a; Cameron, 1917; Cribb, 1947; Brooks, 1970).

In the Taromeo Tonalite between Blackbutt and Nanango, in the area drained by Oaky Creek, are several gold and base metal occurrences. Cobalt mineralisation is reported in one of the gold prospects. On Oaky Creek, about 15 km southeast of Nanango, minor silver lead deposits occur in the Maronghi Creek Beds (Ball, 1901, 1912, 1920b; Brooks, 1959; Cameron, 1916; Denmead, 1934; Sawers, 1967).

Gold, silver, lead, zinc. Deposits of this type occur in the Lower Permian Marumba Beds and Permo-Triassic Kimbla Granodiorite in the Monsildale area 35 km northwest of Kilcoy (Brooks, 1971).

Silver, lead, zinc. On portions 1V and 2V, Parish of St. John, small deposits of silver, lead, zinc and copper occur on Reedy Creek with minor arsenic (Ball, 1920c).

In summary, minor amounts of arsenic, antimony, and mercury are known to occur in the headwaters of streams in the catchment area. The effect of these elements on water quality is not known, but it is recommended that the stream waters be tested.

Of more importance is the likely high manganese content of most of the rocks of the catchment area. The state in which this element occurs is unknown and it is recommended that all stream waters be tested for this element.

Coal

The coal recorded from the sandstone of the Woogaroo Sub-Group near the damsite occurs only in very thin, sporadic seams. The drilling of the damsite did not encounter seams greater than 2.5 cm in thickness (Zahawi, 1970). The sandstone is expected to be underlain at shallow depth by the non-coal bearing Esk Formation. Consequently, coal mining activities in the vicinity of the damsite cannot be expected.

Construction Materials

Considerable volumes of gravel and sand suitable for concrete aggregate are present in the existing river channel and in certain low alluvial terraces within the proposed ponded area. Major deposits of these are outlined on the accompanying map.* Field observations and information from limited drilling indicate that the higher alluvial terraces are composed only of silt and clay.

The gravels are at present too remote from urban areas for economical exploitation, apart from the minor needs for road base and concrete aggregate of local communities such as Esk. However, future expansion of the Ipswich area, together with depletion of existing sources of river aggregate, may make exploitation of the Wivenhoe gravels economically feasible in the long-term future. Unfortunately, at this stage an accurate estimate of the quantities involved cannot be made.

* Map not included in this Appendix.

Despite the intended flooding, exploitation may be possible by a dredging operation in the shallow waters of the reservoir, provided that problems with the resulting suspended sediment can be overcome. For this reason it is suggested that an evaluation of the exposed deposits, and a certain amount of drilling of the likely gravel-bearing terraces, be undertaken before flooding to provide data on location, quantity and quality of deposits. Detailed investigation of the higher, silty terraces is not needed, as the removal of such considerable thicknesses of silty and clayey overburden by dredging would be impractical.

An alternative course of action would be the removal and stockpiling of gravels for future use. However, this would probably be too expensive considering the low cost value of the commodity and the long-term nature of its demand. Limited stockpiling to supply local needs may however be warranted.

Significant deposits of rock suitable for quarrying will not be affected by the reservoir, and sources of clay materials are not known in the area.

Groundwater

In a reconnaissance investigation of groundwater supplies in the Brisbane Valley, Laycock (1967) reports that reasonable supplies of groundwater could be expected from the Cainozoic alluvium along the river, but that little development of such sources had taken place due to the availability of water for irrigation from the river itself. Most of these sources would be gravel bands in low terraces close to the river which would be recharged from the river. Alluvial flats suitable for irrigation will remain above water level in the north of the area, but it is not known if irrigation will be permitted from the reservoir, or from alluvial gravel aquifers.

Groundwater supplies in the rocks of the Toogoolawah Group surrounding the reservoir are reported to be only minor, and in the case of the Neara Volcanics, of poor quality. The effect of the reservoir on supplies in these generally impermeable rocks will be minimal, with only a slight rise in water table immediately adjacent to the shoreline.

Geological Structures

Immediately east of the proposed reservoir area the rocks of the Toogoolawah Group are separated from the older rocks in the D'Aguilar Range by major fault structures forming the eastern edge of the Esk Trough. Although these are now largely inactive, minor earthquakes have been recorded with epicentres on their continuations further to the north (Jones, 1959). The strongest shock of magnitude $m = 5$ occurred near Kilcoy in 1913, while two weaker shocks of undetermined magnitude occurred near Murgon and Mt. Stanley (9 km east of

Nanango) in 1955. Another shock with a magnitude of m = 5.1 which occurred to the east near Mt. Nebo in 1960 was apparently unrelated to any recognised geological situation (Bauer, 1972). The University of Queensland Department of Geology is about to undertake a long-term microseismic monitoring programme to gather more information on the seismicity of the area, and will continue this work after flooding to determine the effect of the reservoir on such activity. Provided consideration is given in the design of the dam to the likely nearby occurrence of shocks such as above, no particular danger in constructing the reservoir in such an area is envisaged.

Special Features of Interest

No geological features of special scientific, scenic or aesthetic value are known in the area to be inundated.

References

BALL, L.C., 1901: in Annual progress report of the Geological Survey for the year 1900. Publs Geol. Surv. Qd, 159.

1906: Mount Langan, Upper Brisbane River. Qd Govt Min. J., 7.

1912: Mines in the Parish of Taromeo. Qd Govt Min. J., 13, 111-112.

BALL, L.C., 1920a: Gold, silver, lead and bismuth mining in the valley of Emu Creek. Qd Govt Min. J., 21.

1920b: The Taromeo silver lead mines. Unpubl. rep., Geol. Surv. Qd.

1920c: The Reedy Creek silver-lead workings near Brisbane. Unpubl. rep., Geol. Surv. Qd.

BAUER, J.A., 1972: The earthquake of 17th November, 1960 in the Mount Glorious region, southeast Queensland. Unpubl. rep., Dep. Geol. Univ. Qd.

BROOKS, J.H., 1957: Manganese occurrence, Fernvale. Unpubl. rep., Geol. Surv. Qd.

1959: Inspection of Taromeo Creek silver-lead deposits M.L. 99 Nanango Gold field. Unpubl. rep., Geol. Surv. Qd.

1970: Request for Departmental Drilling assistance Mount Langan bismuth-silver-gold prospect, Emu Creek Blackbutt. Unpubl. rep., Geol. Surv. Qd.

1971: Departmental diamond drilling programme - Monsildale gold-silver-lead-zinc deposits. Rep. Geol. Surv. Qd, 59.

CAMERON, W.E., 1916: Taromeo copper mine, near Blackbutt Qd Govt Min. J., 17, 58-59.

1917: The Mystery bismuth, gold and silver mine, Mount Langan near Blackbutt. Qd Govt Min. J., 18.

CRIBB, H.G.S., 1947: Mount Langan gold and Emu Creek silver-lead deposits. Qd Govt Min. J., 48.

DENMEAD, A.K., 1934: Golden Bird Pty. Ltd., Blackbutt. Unpubl. rep., Geol. Surv. Qd.

1935: Wolfram and molybdenite workings at Anduramba. Qd Govt Min. J., 36.

1939: Gold deposits at Opossum Creek near Benarkin. Qd Govt Min. J., 40.

1941: Eskdale Antimony lode. Qd Govt Min. J., 42.

JACKSON, C.F.V., 1901: Rising Star and North Star prospecting areas. Qd Govt Min. J., 2.

JONES, O.A., 1959: Queensland earthquakes and their relation to structural features. J. Proc. R. Soc. N.S.W., 92, 176-181.

KROSCH, N.J., 1973: Departmental diamond drilling programme, Eskdale antimony deposits, M.L. 142 Toowoomba. Qd Govt Min. J., 74, 102-109.

LAYCOCK, J.W., 1967: Brisbane Valley groundwater investigations. Unpubl. rep., Geol. Surv. Qd.

MATHISON, C.I., 1967: The Somerset Dam layered basic intrusion, Southern Queensland J. Geol. Soc. Aust., 14(1), 57-86.

O'CONNELL, D.C., 1969: Inspection of the Rising Star copper prospect, Parish of Biarra, near Esk. Unpubl. rep., Geol. Surv. Qd.

1970: Further inspection of Rising Star copper prospect, near Esk, M.L. 152 Toowoomba. Unpubl. rep., Geol. Surv. Qd.

SAWERS, J.D., 1967: Bismuth prospect, M.L. Application 131, Nanango. Qd Govt Min. J., 68, 71-73.

SMITH, H.D., 1969: Authority to Prospect 581M, Fernvale, Queensland. Final Report. Pickands Mather and Co. International. Unpubl. rep., Geol. Surv. Qd Library (C.R. 2901).

WARNER, K.R., 1967: Brisbane River damsites. Geological reconnaissance. Unpubl. rep., Geol. Surv. Qd.

WEBER, C.R., 1968: Reconnaissance Surveys of some Queensland Serpentinites. Geomin Exploration Pty. Ltd. Unpubl. rep., Geol. Surv. Qd Library (C.R. 2368).

WITCHER, I.G., BLOCK, R.Y., and JOHNSTON, W.H., 1969: Authority to Prospect 462M Nanango-Blackbutt-Crows Nest area Southeast Queensland. Report on Exploration for year ended 31.12.1968. C.R.A. Exploration Pty. Ltd. Unpubl. rep., Geol. Surv. Qd Library (C.R. 2771).

ZAHAWI, Z., 1970: Brisbane River damsites. Report on diamond drilling. Unpubl. rep., Geol. Surv. Qd.

APPENDIX 2

REPORT BY QUEENSLAND FISHERIES SERVICE ON IMPACT OF WIVENHOE DAM ON FISH AND FISHING

The following species of native fishes are likely to occur as adults in the Brisbane River upstream of Wivenhoe Pocket: #

Long-finned eel *	Anguilla reinhardti
Bony bream	Fluvialosa elongata
Australian smelt	Retropinna semoni
Freshwater catfish	Tandanus tandanus
Rainbow fish	Nematocentrus fluviatilis
Blue-eye	Pseudomugil signifer
Hardy-head	Craterocephalus marjoriae
Perchlet	Ambassis nigripinnis
Spangled perch	Therapon unicolor
Mouth Almighty	Glossamia aprion
Sea mullet	Mugil cephalus
Freshwater mullet	Trachystoma petardi
Carp gudgeon	Hypseleotris compressus
Firetail gudgeon	Hypseleotris galii
Purple-spotted gudgeon	Mogurnda mogurnda
Striped gudgeon	Mogurnda australis
Lung fish	Neoceratodus forsteri

Those fish which occur as fry and "stragglers" from the estuary have not been listed in this Appendix. The list is essentially comprised of fresh water fish other than the sea mullet and long-finned eel.

* The long-finned eel is the predominant species of eel in the River although the short-finned is also reported as occurring in the area.

Of the fish listed above, the long-finned eel and the sea mullet both require access to the sea to breed. The sea mullet will disappear from the river and tributaries upstream of the Dam, as the structure would be too high to permit the functioning of a conventional fish ladder. In the case of the sea mullet, this will mean its disappearance from the Esk and Toogoolawah districts. Of more significance, however, are the indirect effects on the commercial fishing industry on the southern Queensland coast. Sea mullet is the principal commercial food fish found in Queensland waters and forms one-third to one-half of the landings of fin-fish in the State.

Although essentially marine, this species spends the greater part of its early life in freshwater streams, and the Brisbane River is one of the three most important mullet rivers in the State. The Dam will deny access to about half the freshwater habitat currently available to mullet in the Brisbane River watershed. Although an accurate estimate is impossible, conceivably this could result in a reduction of the order of 10 per cent in the Region's sea mullet run, which, at the worst estimate, could represent a potential loss to the industry of about $100 000 annually.

On the other hand, impoundment will provide a very considerable lacustrine habitat less than fifty miles distant from Brisbane. If a suitable species can be found to stock the lake and provided that the authority in charge of administration of the Dam permits angling activities therein, a considerable potential exists to develop freshwater angling opportunities close to the main concentration of the State's population.

APPENDIX 3

IMPACT OF WIVENHOE DAM ON FISH
BY PROF. J.M. THOMSON

The Fish Fauna

The only species of fish of commercial importance likely to migrate into the upper Brisbane River is the Sea Mullet (Mugil cephalus). The young of a number of estuarine species are known to wander into fresh water and presumably individuals or groups of individuals of these species must from time to time reach the upper Brisbane River. This conclusion is based on studies on the freshwater zone of the Albert and Logan Rivers as a detailed survey of the fish of the upper Brisbane River is lacking.

The species involved are mainly:

The Fan-tail Mullet	Mugil georgii
The River Garfish	Hemirhamphus ardelio
The Snub-nosed Garfish	Arramphus sclerolepis
The Estuary Catfish	Cnidoglanis macrocephalus
The Ox-eye Herring	Megalops cyprinoides
The Black Bream	Mylio australis
The Silver Bream	Rhabdosargus sarba
The Old Wife	Enoplosus armatus

These species appear in freshwater only as fry and rarely occur there after their first year of life.

The only migratory fish other than the sea mullet that remains in the freshwater zone till it reaches a large size is the short-finned Eel (Anguilla australis). Although a minor commercial fishery for this species exists near Newcastle, N.S.W., this species is not subject to commercial exploitation in Queensland. It does provide a possible angling catch for anglers in the freshwater zone, though many Australians have an entirely unjustified feeling of repulsion about eels and will not eat them.

The Sea Mullet can be caught by line but their capture requires skill and the use of hooks much finer than those normally used.

The native freshwater fish that can provide a catch for the angler are confined to four species: the Freshwater Jewfish or River Catfish (Tandanus tandanus), the Long-tailed Catfish (Euristhmus lepturus), the Spangled Perch (Therapon unicolor) and the Freshwater Mullet (Trachystoma petardi). As well as these there are several species of small-sized fish which do not grow large enough to attract attention.

A notable absentee from the above list is the Australian Bass (Percalates colonorum), which appears not to inhabit the Brisbane River although it is found in the Noosa River, the Pine River and the Nerang River. Possibly its absence from the upper Brisbane River is associated with the fast run and the rapids as they appear to prefer slow-moving streams.

The probable effects of a dam

(a) without a fish ladder

The migratory fish, and in particular the Sea Mullet, would no longer be able to reach the waters above the dam and within a few years the mullet already above the dam would die out, decreasing the diversity of fish available to the local fishermen. Whether eels would be barred from movement upstream would depend on the nature of the dam, the season of suitable discharge flow rates and the topography of the country at the end of the dam walls. Eels are tenacious in their attempts to get upstream and where there is any dampness will climb a dam wall (if not too high) or climb around it if and when the adjacent banks are wet with rain.

The effect of barring mullet from the upper reaches of the river would in my opinion have little effect on the mullet stocks of Moreton Bay. Sea mullet in freshwater are usually in small scattered groups, not in the schools of considerable size that are typical in the estuarine environment. Also due to pollution in the lower reaches of the Brisbane River the large schools of mullet which once habitually entered the estuary have not been a feature in recent years yet the mullet stocks of Moreton Bay have not declined.

Even if the mullet which previously ran to the upper Brisbane River are counted as a total loss when the dam is built, the value to the commercial fishery would have been small. The U.S. Corps of Engineers in assessing the need for fish ladders on American streams uses as a guide the criterion that the worth of the fish threatened must be 4% of the cost of the structure to warrant expenditure on a fish ladder. Even putting a benefit value on to the mullet which local farmers, etc. may take from the upper Brisbane River, their value could not approach this sum.

(b) with a fish ladder

If a properly designed fish ladder were built the benefits would be to perpetuate the run of sea mullet and the upstream migration of the eels. It is doubtful if the fry of other estuarine species would have the capacity to swim against the rapid currents which necessarily exist in the flume of a fish ladder.

There are constraints on the construction of fish ladders if they are to be effective. It is easy to design a ladder with a determined discharge and flow rate but to be effective the ladder must take into account the biological properties of the fish. Many a physically well-designed fish ladder has failed to fulfil its function because the entrance point downstream for ascending fish was sited too far downstream of the dam wall and/or not opening from the main flow of the water. Fish will follow the strongest currents upstream and in doing so may by-pass the fish ladder entrance if it is sited too far from the main flow. The fish simply approach the normal discharge point of water from the dam and fail to get upstream. Experience also shows that fish enter a ladder more readily if the flow from the ladder is in the same direction as the main flow of the river. Power dams present special difficulties because during the dry season of the year the whole flow, or most of it, passes through the turbines and issues via the turbine's tail race. During wet weather the main flow may be via the spillway and this discharge rarely reaches the river at the same place as the tail race. Hence such dams really need two ladders, one at the tail race and one at the spillway.

Within the fish ladder there are physical aspects of design which must take account of the fish's swimming powers. Fish can swim at a high speed for short periods only. It would be impossible for a fish to mount a dam wall of any height via its fish ladder if that ladder had a constant flow greater than the fish's average swimming rate along the whole length.

There are 5 or 6 basic design types of fish ladders. The type selected varies with the gradient involved, current flow rates, etc.. In general it may be said that fish pass more easily from one pool to another in a fish way if the orifice leading from one pool to the next is submerged. Fish will pass over a shallow spillway between pools, but not so readily. There are also problems in siting the upstream exit from the ladder, mostly as a function of design as a result of varying water levels during the year.

Doubts have been raised about whether fish would find their way to the exit point when moving downstream. The theory suggests that coming down river the fish drift or swim with the current but on entering the essentially standing water of the dam they would have no guide posts to lead them to the dam and the exit by the fish ladder. However, mullet successfully find their way to the exit from coastal lakes, such as Noosa Lakes or Lake Macquarie, after entering them from their in-flowing rivers and creeks. Studies at Lake Macquarie indicate that mullet move about continually following the shores of the lake around. Presumably they would behave similarly in an impoundment of water and follow the shore line to the dam where proper siting of the exit for the ladder should lead them downstream.

The gravest problem for downswimming fish at the dam face is counterattraction offered by the pull of the turbine race and at times the flow over the spillway. Protection of turbines from entry of fish has been a major problem in American power dams.

Diversification of species

The major argument in favour of a fish ladder would appear to be maintenance of the diversity of fish species above the dam. This object could be achieved, though with different species, by the introduction of new fish into the river or dam. Yellow-belly (Plectroplites ambiguus) would seem an obvious choice. Although this fish is typical of the Murray-Darling system, it also exists already in the Dawson River. The periodic flooding of shallow ground near the lake edge during the rainy season may well provide the type of environment they seem to need for successful spawning.

A stocking programme would cost a fraction of the amount needed for a fish ladder.

APPENDIX 4

BRISBANE CITY COUNCIL

DEPARTMENT OF WATER SUPPLY AND SEWERAGE

CITY CHEMIST'S LABORATORY

BRISBANE RIVER - CATCHMENT AREA

WIVENHOE DAM PROJECT

MEMORANDUM: City Chemist

Date ______________

Sampled By: ____________________

Chlorinated Pesticide Survey

The following results were obtained on samples from the Brisbane River - Catchment Area

Date of Sampling: ______________

Chlorinated Pesticide Levels Expressed in p.p.t.	Location No.											
	Blank	1	2	4	6	8	12	15	16	17	20	23
1. Total B.H.C. (includes α, β + γ Isomers)												
2. α - Endosulfan												
3. Heptachlor												
4. Aldrin												
5. Heptachlor Epoxide												
6. o,p D.D.E.												
7. p,p D.D.E.												
8. o,p D.D.D.												
9. Dieldrin												
10. Endrin												
11. p,p D.D.D.												
12. o,p D.D.T.												
13. p,p D.D.T.												
14. Methoxychlor												
15. 2,4D												
16. 2,4,5T												
17.												
18.												

p.p.t. = part per trillion = ng/litre = 10^{-9} gram/litre

Location:

1. Bremer R. U/S Ipswich
2. Bremer R. D/S Ipswich
4. Brisbane R. Mt. Crosby
6. Lockyer R. O'Reilly's Weir
8. Brisbane R. Wivenhoe
12. Brisbane R. Mt. Beppo Rd.
15. Sheep Station Creek
16. Kilcoy Creek
17. Sandy Creek
20. Esk Creek
23. Sandy Ck. Bryden Rd.

Chemist

BRISBANE CITY COUNCIL

DEPARTMENT OF WATER SUPPLY AND SEWERAGE

BRISBANE RIVER - CATCHMENT AREA

WIVENHOE DAM PROJECT

CITY CHEMIST'S LABORATORY

Date ____________________

Inorganic Results

MEMORANDUM:

Sampled By: ____________________

Date of Sampling: ____________

The following results were obtained on samples from the Brisbane River - Catchment Area

Sample No.	Sampling Location	Appearance Sampler's Remarks	Flow cu mec	Time	Temp. ^{o}C	pH	Turbidity F.T.U.	Colour Co-Pt. Units	Alkalinity mg/1 CO_3	Carbon Dioxide mg/1 CO_2	Total Hardness mg/1 $CaCO_3$	Calcium mg/1 $CaCO_3$	Magnesium mg/1 $CaCO_3$	Chloride mg/1 Cl	Sulphate mg/1 SO_4	Sodium mg/1 Na	Potassium mg/1 K	EC_{25} millimhos/cm	T.D.S. mg/1	Ammonia mg/1 N	Nitrate mg/1 N	Phosphate mg/1 PO_4	Silica mg/1 SiO_2

BRISBANE CITY COUNCIL

DEPARTMENT OF WATER SUPPLY AND SEWERAGE

BRISBANE RIVER - CATCHMENT AREA

WIVENHOE DAM PROJECT

CITY CHEMIST'S LABORATORY

Date ____________________

Trace Metals and Pollution Results

Date of Sampling: ______________

MEMORANDUM: City Chemist

Sampled By: __________________

The following results were obtained on samples from the Brisbane River - Catchment Area

* NOTE: 1 yg/l = 10^{-3} mg/l

Sample No.	Sample Location	Mercury ug/l Hg *	Zinc ug/l Zn *	Copper ug/l Cu *	Nickel ug/l Ni *	Cadmium ug/l Cd *	Barium ug/l Ba *	Chromium ug/l Cr *	Lead ug/l Pb *	Tin ug/l Sn *	Arsenic ug/l As *	Antimony ug/l Sb *	Iron ug/l Fe *	Iron Fe * (unfiltered sample) ug/l	Manganese ug/l Mn *	Manganese Mn* (unfiltered sample) ug/l	Silver ug/l Ag *	Aluminium ug/l Al *	T.I.C. mg/l C	T.O.C. mg/l C	S.S. mg/l

BRISBANE CITY COUNCIL

DEPARTMENT OF WATER SUPPLY AND SEWERAGE

BRISBANE RIVER - CATCHMENT AREA

WIVENHOE DAM PROJECT

MICROBIOLOGICAL RESULTS

CITY CHEMIST'S LABORATORY

MEMORANDUM: City Chemist

Date ____________________

2. Algae

Sampled by: ____________________

The following results were obtained on samples from the Brisbane River - Catchment Area

Date of Sampling: ____________

Sample No.	Location	Pre Incubation							Post Incubation							Initial Count Probable Effect of Algae Present
		Date Examined	Initial Algal Count Orgs/ml	Predominant General	%	Amorphous Material No./ml	Other Organisms Type	Other Organisms Count %	Date Examined	Final Algal Count Orgs/ml	Predominant General	%	Amorphous Material No./ml	Other Organisms Type	Other Organisms Count Orgs/ml	

BRISBANE CITY COUNCIL

MEMORANDUM: City Chemist

Sampled By: ____________

DEPARTMENT OF WATER SUPPLY AND SEWERAGE

BRISBANE RIVER - CATCHMENT AREA

WIVENHOE DAM PROJECT

MICROBIOLOGICAL RESULTS

CITY CHEMIST'S LABORATORY

Date ____________

1. Bacteriology

Date of Sampling: ____________

The following results were obtained on samples from the Brisbane River - Catchment Area

Date Examined	Sample No.	Location	Total Coliforms /100 mls	Faecal Coliforms /100mls	Plate Count /ml	Pathogens Isolated (Type)	Remarks

APPENDIX 5

CATTLE DIPPING - WIVENHOE DAM CATCHMENT BY DEPARTMENT OF PRIMARY INDUSTRIES

The hazard, or otherwise, posed by the use of veterinary acaricides in conjunction with grazing in the catchment of the Wivenhoe Dam may be considered in general or specific terms.

General considerations discussed under specific sub-headings are as follows:-

1. Chemicals

The availability of all agricultural chemicals is regulated by the Agricultural Standards Acts. Registration for use follows assessment of both their efficacy and the hazard associated with their proper use. This assessment is by separate national committees set up by the Agricultural Council and the National Health and Medical Research Council. In addition to meeting the requirements of the Agricultural Standards Acts veterinary acaricides must also be acceptable in terms of the Stock Acts, which prescribe and proscribe the use of specific chemicals for the purpose.

The functioning of these Acts, the nature of the dipping operation and the demands of the consumers of animal products here and overseas combine to ensure that these chemicals are of low mammalian toxicity and are not significantly persistent in biological systems. Although, by necessity, not as ephemeral as horticultural chemicals of the same chemical class, they are readily degraded both by photodegradation and in biological systems and present no long term hazard to aquatic fauna. The immediate hazard is confined to newly formulated chemicals as, by chance, they are all virtually insoluble in water. The traditional and virtually passé arsenical acaricide is an exception to most of these considerations but can be rendered virtually insoluble in water and fixed in the soil by special treatment. Because of the nature and spectrum of resistance to chemicals exhibited by ticks in Queensland generally and in this area in particular, it is likely that different chemicals and indeed a new and different class of chemical may provide the active materials in vats in the catchment of the dam when completed.

Other than the chance consideration of water solubility any consideration generally applied to the current acaricides will apply also to these chemicals.

2. Dipping operations

The dipping of cattle, unlike most applications of agricultural chemicals, is a closed system. The aim of the system is to preserve the dip wash for re-use. By commercial necessity stripping of the active material, although it occurs, is kept to a minimum. A dip wash of average concentration (0.075%) would, even if the stripping factor was 2 to 1, deposit no more than 3 or 4 grams of active material on a mature beast and this would be largely degraded within 4 days. The escape of chemicals is minimal.

3. Emptying the vat

Vats have their contents discharged when their effectiveness is reduced to an unacceptable level. This may arise from a gradual accumulation of solid debris or more suddenly from the degradation of the active material or the selection of a resident tick population resistent to the acaricide in the vat.

In a newly charged vat the active material is dissolved in the solvent of the formulation and this emulsifies in the water of the vat. As the vat matures solvent is lost and the insoluble active material is adsorbed on clay or organic debris. In operation a vat requires manual stirring and the use of stirrer-cattle before use. At the time of discharge the vat fluid consists of a supernatent containing little active material and a sediment of debris containing the active material. In practice the supernatent is discharged by pumping over grass and presents little hazard as the material is readily degraded in these circumstances. The sediment should be spread in an area not adjacent to watercourses and allowed to degrade. No direct discharge to water is recommended. In considering vat discharge it should be noted that a standard sized vat at 0.1% strength would contain less than 15 kilograms of active material that is already adsorbed on solids. It would carry to water only if the solids were carried also and would then precipitate with the solids.

Accidental discharge could occur in time of flood but here the hazard is minimal. If the flood is, as usual, a back-water flood, the vat fluid consisting of an active sediment and a largely inactive supernatent is virtually unaffected by inundation. A badly located vat, subject to scouring by flash flooding could discharge some active material but it would be largely adsorbed on debris that would settle in the watercourse and not be available to aquatic fauna.

The incorrect storage and disposal of formulated acaricides in containers could provide active material to a water system but dilution factors and the nature of the chemicals would make for a local and transient hazard. This, however, is the most likely hazard to water supplies.

There has been some discussion regarding the vats as a potential source of phosphate to the water supply. An organophosphate vat contains less than 2 kilos of phosphorus at recommended strength. However a restricted range of acaricides require super phosphate as a buffer in the vat. Use would be restricted to one or two hundred pounds per vat which is insignificant compared with agricultural use. While dissolved phosphate will readily carry to water in streams it is rapidly fixed by passage through soils and unlike nitrogen is not leached.

It is not likely that acaricides requiring buffering will be commercially viable given competition with new chemicals now available and its use can be regarded as a transient phenomenon.

In summary the use of veterinary acaricides is not considered to present any significant hazard to water quality. Even minor hazard can be reduced by locating vats away from proximity to watercourses and preferably on sites that have indirect drainage to the dam.

A table is attached giving a composite of toxicity data and also the residue tolerances of foodstuffs of animal origin recommended by the appropriate sub-committee of the National Health and Medical Research Council. These tolerances are not safety levels but are the lowest levels consistent with good agricultural practice. They give some indication of what is acceptable and exceed any levels likely to occur in water supplies.

TOXICITY AND RESIDUE DATA FOR VETERINARY ACARICIDES

Chemicals	Milligrams per kilogram	Parts per million
Dursban	MLD sheep 200	2.0 meat fat
	LD_{50} rats 160	
Nexagan	LD_{50} rats 250	3.0 meat fat
Asuntol	LD_{50} sheep 25	0.5 meat fat
Ethion	LD sheep 50	2.5 meat fat
Delnav	LD_{50} rats 20-100	1.0 meat fat
	LD calf 10	
Trithion	LD_{50} rats 20	1.0 meat fat
	LD sheep 25	
Sevin	LD_{50} rats 400-800	1.0 meat
Promicide	LD_{50} mice 1200	0.5 meat
Bimarit	LD_{50} rats 3000	2.0 meat fat
	LD calf > 500	
Diazinon	LD_{50} mouse 90	
	LD calf 10	
Chlorphenamidine	LD_{50} rat 250	1.0 meat fat

APPENDIX 6

TERMS USED IN ECONOMIC AND FINANCIAL ANALYSIS

Interest Rate

The interest rate is the price one person pays to use the capital of another person. It is the price of money and it is determined by the capital market. Interest rates are used to examine financial questions such as cost sharing, funding, charges, etc.

Discount Rate

Because $1 received in the future is worth less that $1 received now, it is not possible to compare the time streams of expenditures and receipts arising from alternative projects unless expected receipts and expenditures are 'discounted' to arrive at their present value or present worth. The discount rate or discount factor is a value judgment by the analyst or the decisionmaker, depending on who decides on the rate. Public funds can be used for a particular project, for other public works, or they can be left for investment in the private sector by not raising public loans or levying taxes. If the public funds are used for a particular project there is no opportunity to use these funds for other public or private works. The discount rate acts in some way to measure the social opportunity cost of the capital invested in the project. Three discount rates - 8%, 10% and 12% - have been used in this text to test the sensitivity of the analysis to different rates.

The discount rate is used in all the economic analyses. It is only coincidental that in this report the interest rate is of approximately the same order as the discount rate.

Planning Period

The Planning Period or Planning Horizon is the most distant future time (75 years) considered in this study for the purpose of analysis.

Present Worth

If the year by year expenditures (receipts) for the planning period for a particular project are discounted at the appropriate discount rate, the sum of the discounted expenditures (receipts) is the present worth of the expenditures (receipts). The net present value or net present worth is the difference between the sum of the discounted expenditures and the sum of the discounted receipts. Present worth always refers to a particular time base which may be in the future.

Equivalent Annual Value

The net present value can be converted into an equivalent number of annual instalments evenly spread over the planning period. By investing in the project rather than by investing elsewhere, at an interest rate equal to the discount rate, the community will be better off by the equivalent of the 'equivalent annual value' each year for the planning period. The equivalent annual value is the equal annual amount that could be provided each year of the planning period if the net present value was invested at an interest rate equal to the discount rate. Similarly an equivalent annual cost and an equivalent annual benefit can be obtained.

Risk

An event is subject to risk when the outcome of that event is uncertain but can be represented by a known probability distribution of outcomes.

Uncertainty

An event is subject to uncertainty when the outcome of that event is uncertain and can only be represented by a subjective probability distribution.

APPENDIX 7

FLOOD MITIGATION - AN ECONOMIC AND SOCIAL EVALUATION

General

'Flood Mitigation' is considered in more detail than in Section 11: 'Flood Mitigation'. The aspects of risk and uncertainty and floodway clearance are considered at some length. The terms interest rate, discount rate, planning period, present worth, equivalent uniform annual cost (or benefit), risk and uncertainty, used in the analysis, are defined in Appendix 6.

Time Profiles of Expenditure and Costs

The Co-ordinator-General's Department prepared in September 1975 a tentative expenditure programme for the construction of the Dam assuming a commissioning date of 30th June, 1982. The costs applied to a dam of F.S.L. EL 67 AHD and crest level of EL 79 AHD. As a variety of dam sizes was examined in this study, the Co-ordinator-General's Department's programme was used as a basis for developing time profiles of expenditure for each of the major categories of the work. The distributions of expenditure used in the analysis are listed in Table A7.1. Also shown are the revised estimates of expenditure as at January 1977. The use of the earlier distribution of expenditure underestimates discounted costs in Table A7.2 by about 5 per cent. The effect of this error on the conclusions of the analysis is minimal.

TABLE A7.1

EXPENDITURE TIME PROFILES

Year	Per cent by Year by Works Category			
	Estimates used in Analysis		Revised estimates of Jan. 1977	
	Land Acquisition	Dam & Services Relocation	Land Acquisitions	Dam & Services Relocation
1972/73	2.4	-	4.1	0.2
1973/74	11.7	-	17.2	0.7
1974/75	19.3	-	16.0	2.4
1975/76	24.4	-	24.7	4.0
1976/77	22.0	-	14.5	13.2
1977/78	11.4	-	10.7	16.9
1978/79	6.3	25.0	4.3	14.3
1979/80	2.5	25.0	2.2	20.5
1980/81	-	25.0	2.1	16.7
1981/82	-	25.0	2.1	7.4
1982/83	-	-	2.1	3.7

The costs which have to be incurred over and above urban water costs (F.S.L. EL 67 AHD) to provide flood storage were obtained from the Irrigation and Water Supply Commission (21). These costs, together with present worth and equivalent uniform annual costs for a base year of 1981/82 expressed in 1974 money values, are presented in Table A7.2. Section 12: 'Cost Allocation and Çost Sharing' discusses the appropriateness of using incremental costs.

TABLE A7.2

COSTS OVER AND ABOVE URBAN WATER COSTS FOR VARYING FLOOD STORAGES (1974 MONEY VALUES)

Costs	Flood Storage - Ml			
	500 000	800 000	1 100 000	1 400 000
	$M	$M	$M	$M
Total: Dam	0.62	0.95	2.41	3.86
Land Acquisition	2.40	4.24	6.09	9.52
Relocations	0.83	1.46	2.09	2.72
Total	3.85	6.65	10.59	16.10
Present Worth of Costs 1981/82				
8% p.a.	5.41	9.40	14.68	22.44
10% p.a.	5.88	10.23	15.90	24.31
12% p.a.	6.42	11.16	17.26	26.45
Equivalent Uniform Annual Cost as from 1981/82 (75 year planning period)				
8% p.a.	0.433	0.752	1.174	1.795
10% p.a.	0.588	1.023	1.590	2.431
12% p.a.	0.770	1.339	2.071	3.174

Stage Damage and Damage Probability Curves

Using the stage damage curve derived by the Snowy Mountains Engineering Corporation (23), (31) and the historic flood height data (27), (28), damage probability curves were derived for the 1974 stage of development in the flood plain at 1974 money values. The 'best fit' curves were obtained by means of a procedure developed by Bobée (36). Curves were fitted to permit analysis of risk and uncertainty. Expected equivalent uniform annual damage for the range of flood storages was determined from the areas under the curves. The expected equivalent uniform annual damage in the Somerset Dam only case has been assessed as $6.18M. The reduction in expected equivalent uniform annual damage between the Somerset Dam only case and the particular Wivenhoe flood storage was defined as the expected equivalent uniform annual benefit for that storage. See Table A7.3. A range of expected equivalent uniform annual benefits over a 75 year planning period was obtained by applying a range of possible growth rates to development in the Valley. The results are shown in Table A7.4. Note that the flood storages tabulated are the flood compartments for various sizes of Wivenhoe Dam, additional to the existing Somerset Dam flood storage capacity.

TABLE A7.3

TOTAL EXPECTED EQUIVALENT UNIFORM ANNUAL BENEFITS - ($M)
Mid 1974 Development and Money Values
Discount Rate 10% - 75 year planning period

Somerset Dam plus a Wivenhoe Dam Flood Storage of (Ml)	Expected Equivalent Uniform Annual Benefit ($M)	Residual Expected Equivalent Uniform Annual Damage ($M)
None (Somerset Dam only)	0	6.18
500 000	2.78	3.40
800 000	3.91	2.27
1 100 000	4.97	1.21
1 400 000	5.28	0.90

TABLE A7.4

TOTAL EXPECTED EQUIVALENT UNIFORM ANNUAL BENEFITS ($M)
Mid 1974 Development + Growth and 1974 Money Values
75 year planning period

Wivenhoe Dam Flood Storage of (Ml)	Discount Rate								
	8% p.a.			10% p.a.			12% p.a.		
	Growth Rate p.a.			Growth Rate p.a.			Growth Rate p.a.		
	1%	2%	5%	1%	2%	5%	1%	2%	5%
500 000	3.20	3.74	6.80	3.12	3.54	5.66	3.06	3.40	4.96
800 000	4.50	5.26	9.65	4.39	4.97	7.96	4.31	4.78	6.98
1 100 000	5.72	6.68	12.26	5.57	6.32	10.12	5.47	6.08	8.88
1 400 000	6.08	7.10	13.03	5.92	6.72	10.75	5.82	6.46	9.43

Optimum Flood Storage -'Total Benefits' Approach

The optimum size storage for a given benefit-cost relationship is defined as that size beyond which marginal benefits will be less than marginal costs. Applying this criterion, a range of optimum size storages corresponding to the choice of discount rate and growth rate was obtained, as set out in Table A7.5. The sizes ranged from 1 050 000 Ml for zero growth and 12 per cent per annum discount rate to 1 290 000 Ml for 5 per cent per annum growth and an 8 per cent per annum discount rate. The results were not sensitive to the assumptions re growth rates or to the discount rate selected.

TABLE A7.5

OPTIMAL FLOOD STORAGE SIZE (Ml)
(No complementary non-structural measures)

Discount Rate % p.a.	Growth Rate % p.a.		
	0%	2%	5%
8%	1 100 000	1 175 000	1 290 000
10%	1 090 000	1 160 000	1 260 000
12%	1 050 000	1 100 000	1 150 000

Risk

The above analysis was confined to considerations of the expected equivalent uniform annual damages and benefits. However, because of the random pattern of arrival of flooding events and the short usable record of flooding in the Brisbane River (89 years), it was considered that the significance of these considerations should be examined in more detail.

Risk in the economic sense arises because the sequence of damaging floods in the future will be random over time. That is, following the construction of the flood storage, there is a small but finite chance, for instance, that no damaging floods might occur within, say, the next 75 years. Conversely, the next 75 years may be a period with highly damaging floods in almost every year. Again, immediately following the provision of the storage, major flooding events may occur followed by a lengthy flood-free period or the reverse may occur where a lengthy flood-free period follows the provision of the storage with the first major flooding many years into the future. The actual equivalent uniform annual benefit realised from the provision of the flood storage as opposed to the expected equivalent uniform annual benefit may conceivably range from a very low to a very high value.

The results of this analysis for a 10 per cent per annum discount rate and a 75 year planning period (no growth) are listed in Table A7.6.

TABLE A7.6

EQUIVALENT UNIFORM ANNUAL BENEFITS AND RISK

Flood Storage Size (Ml)	Per cent Risk that Actual Benefits $\leq$ Amount Shown ($M)				Expected Equivalent Uniform Annual Benefit ($M)	Equivalent Uniform Annual Cost of Storage ($M)
	20%	40%	60%	80%		
500 000	1.0	1.9	3.1	5.0	2.78	0.588
800 000	1.2	2.4	4.1	6.8	3.91	1.023
1 100 000	1.3	2.6	4.8	8.1	4.97	1.590
1 400 000	1.3	2.8	5.1	8.9	5.28	2.431

The corresponding risk that realised benefits will be less than costs are 11%, 16%, 22% and 35% for flood storages of 500 000, 800 000, 1 100 000 and 1 400 000 megalitres respectively.

The analysis of the risk that benefits might be less than costs was pursued further. The optimum size storage was examined to see how it would vary if a certain maximum risk level was specified as a criterion for investment. The results of this analysis are presented below in Table A7.7 in the form of the optimum size flood storage for a specified risk.

The Table shows the per cent risk that the specified storage will be smaller than the justified optimum size.

TABLE A7.7

SPECIFIED RISK PER CENT THAT NOMINATED FLOOD STORAGE IS LESS THAN OPTIMUM
10 per cent per annum discount rate, zero growth, 75 year planning period

Risk Per cent	78%	45%	30%	25%
Nominated Flood Storages (Ml)	500 000	800 000	1 100 000	1 400 000

While the expected values of benefits should be used as the guiding principle in any investment decision, due recognition should be given to the risk associated with the final investment. Risk considerations may affect the decision in a particular case when other equally 'attractive' investments from the point of view of expected returns are available.

Uncertainty

The analysis of risk assumes that the probability of any damaging flood is known with certainty. However, this is not the case. Only a short time period of usable flood records is available (in this case 89 years) from which to draw inferences about the probabilities of occurrence and consequently there is likely to be uncertainty resulting from sampling errors in flood distribution. The error is likely to be small for the more frequent small floods but the errors could be quite large for the rarer flooding events which also happen to be potentially the most damaging.

Consideration of the likely consequences of uncertainty on the analysis is therefore warranted. Applying standard statistical techniques, such as those described by Kite (37), the following distributions of expected benefits were obtained for a range of flood storage sizes - Table A7.8. The mean value of the expected equivalent uniform annual benefit shown in Table A7.8 is the mean value of the distribution of all the expected equivalent uniform annual benefits.

TABLE A7.8

EXPECTED EQUIVALENT UNIFORM ANNUAL BENEFITS AND UNCERTAINTY
10 per cent per annum discount rate, zero growth, 75 year planning period

Flood Storage Size (Ml)	Per Cent Confidence Expected Equivalent Uniform Benefits ≥ Amount Shown ($M)					Mean Value of Expected Equivalent Uniform Annual Benefit ($M)	Equivalent Uniform Annual Cost of Storage ($M)
	90%	80%	60%	40%	20%		
500 000	1.9	2.5	3.2	3.7	4.8	2.78	0.588
800 000	1.9	2.8	4.6	8.5	14.3	3.91	1.023
1 100 000	1.9	2.9	5.2	10.2	25.9	4.97	1.590
1 400 000	1.9	2.9	5.3	11.2	33.4	5.28	2.431

The chance that due to uncertainty the expected benefits will be less than costs is less than 1%, 1.5%, 3.5% and 15%, for flood storages of 500 000, 800 000, 1 100 000 and 1 400 000 megalitres respectively.

A further analysis gave the following values of confidence that the choice of a particular size flood storage will be smaller than the justified optimum size - Table A7.9

TABLE A7.9

SPECIFIED CONFIDENCE LEVEL THAT NOMINATED FLOOD STORAGE IS GREATER THAN OPTIMUM
10 per cent per annum discount rate, zero growth, 75 year planning period

Confidence Level (Per Cent)	13%	25%	48%	68%
Flood Storage (Ml)	500 000	800 000	1 100 000	1 400 000

The Table illustrates, for example, that there is a 68% chance that a 1 400 000 megalitres flood storage will prove to be larger than optimum over the 75 year planning period. The analysis indicates that conclusions drawn from the short period of flood records are highly sensitive to hydrologic uncertainty. Fortunately in this case, the chance of the investment realising benefits less than costs due to uncertainty is relatively low. In the case of a 1 400 000 megalitres flood storage there is about an 85 per cent chance that benefits will exceed costs and further there is an estimated 32 per cent chance that a larger storage could have been justified.

Residual Damage

The emphasis until now in the analysis described has been on benefits and how these are influenced by risk and uncertainty and the consequent implications on investment recommendations. While these benefits are measured as reduced damage, it is to be remembered that there will still be residual flood damage for any chosen flood storage. Since the level of residual damage is of significance to existing and potential development in the flood plain areas, e.g. with respect to location decisions, flood insurance premiums, etc., it deserves separate consideration. With Somerset Dam alone, the expected equivalent uniform annual damage on the flood plain at mid 1974 stage of development and mid 1974 prices is $6.18M.

In the case of Somerset Dam plus a 1 400 000 megalitres flood storage in Wivenhoe Dam, expected residual equivalent uniform annual damage at the 1974 level of development and 1974 money values has been assessed as $0.9 million. See Table A7.3. A risk analysis indicates that there is about a 30 per cent chance that the residual equivalent uniform annual damage could be greater than this. See Table A7.10.

TABLE A7.10

RESIDUAL EQUIVALENT UNIFORM ANNUAL DAMAGE AND RISK
1 400 000 Megalitres Flood Storage
10 per cent per annum discount rate, zero growth,
75 year planning period

Per cent Risk that Residual Equivalent Uniform Annual Damage ≥ Amount Shown ($M)					Mean Value of Expected Residual Equivalent Uniform Annual Damage ($M)
90%	80%	60%	40%	20%	
0.11	0.17	0.32	0.64	1.68	0.9

The results when uncertainty is analysed are given in Table A7.11.

TABLE A7.11

EXPECTED RESIDUAL EQUIVALENT UNIFORM ANNUAL DAMAGE AND UNCERTAINTY
1 400 000 Megalitres Flood Storage
10 per cent per annum discount rate, zero growth,
75 year planning period

Per cent Confidence that Residual Equivalent Uniform Annual Damage ≥ Amount Shown ($M)					Mean Value of Expected Residual Equivalent Uniform Annual Damage ($M)
70%	60%	50%	40%	30%	
0	0.3	1.7	5.6	14.6	0.9

There is approximately a 55 per cent chance that expected residual equivalent uniform annual damage will be greater than or equal to the $0.9M. The above assumes mid 1974 money values and stage of development in the flood plain. Development in the flood plain since 1974 would result in higher residual equivalent uniform annual damage.

Uncertainty considerations make it clear that no occupant of the flood plain can ever really know the true flood hazard. This should be taken into account when formulating regulatory controls on flood plain development or in the development of flood plain zoning schemes. It is also important in flood insurance schemes.

Non-Structural Measures

In Section 11: 'Flood Mitigation' - a combination of structural and non-structural measures was suggested as necessary if all the benefits of the Dam were to be realised. Further, it was suggested that there is a need to establish a 'socially acceptable' flood hazard so that the community, by planning, could ensure that no individuals through ignorance are exposed to hazards greater than this limit. The community at large also has the right to protect itself from the claims of individuals who know of the flood hazard but still locate in flood hazardous areas.

There is a range of opinion on what constitutes a 'socially unacceptable' degree of hazard and the decision is, in the end, subjective. The decision can, however, be guided by the economic costs incurred in adopting a particular hazard level and by consideration of the social hardships experienced by flood plain occupants subjected to periodic flooding. Table A7.12 showing the risk of flooding can be used as a basis for assessment of the likely social hardship to be experienced in the case of Wivenhoe Dam.

TABLE A7.12

RISK OF FLOODING

Probable Frequency of Flooding	Risk that Intervals between Floods of this Magnitude $\leq$ Interval specified			
	50%	25%	10%	5%
1 : 100	69 yrs.	29 yrs.	11 yrs.	5 yrs.
1 : 30	21 yrs.	8 yrs.	4 yrs.	2 yrs.

Structural means, such as Wivenhoe Dam, by reducing the flood hazard, can be used to reduce flood damage in developments that have been approved at too low a level in the flood plain. Experience has shown that structural measures encourage further development and continuing encroachment into areas of high flood hazard. If the benefits of the flood storage are not to be lost, complementary non-structural measures (zoning, land use regulation etc.) are needed.

A method of analysis has been adopted that aims to distinguish between development above the 'socially acceptable' flood hazard level and developments below that level. The approach can be used to show the costs that have to be incurred to reduce flood damage in developments still below the 'socially acceptable' flood hazard level by initially selecting the optimum storage size on the basis of benefits accruing to development above the 'acceptable' flood hazard level. Any additional costs incurred can then be identified as those necessary to correct development approvals agreed to in the past either in a mistaken view of the likely flood damage or because of a too optimistic view of the flood mitigating effect of engineering structures. The costs of reducing flood damage in areas still below the particular 'socially acceptable' flood hazard level adopted are costs over and above those 'justified' in economic terms.

An analysis based on a 'socially acceptable' flood hazard level, i.e. the 'regulatory' flood, assumes that non-structural measures such as flood plain zoning, subdivisional and building regulations etc. are in force so that encroachment onto the flood plain at levels above the 'socially acceptable' flood hazard level are regulated to flood tolerant activities and so that there is no continuing encroachment onto areas below the 'regulatory' flood level.

Redefining Benefits

There is therefore a need to revise the earlier findings, based on total benefits to all development. An analysis using a range of possible 'socially acceptable' flood hazard levels was performed. For each hazard level in turn, development above and below this level was identified - See Figure A7.1 - for the case of Somerset Dam only and for the case of Somerset Dam plus an added flood storage in Wivenhoe Dam.

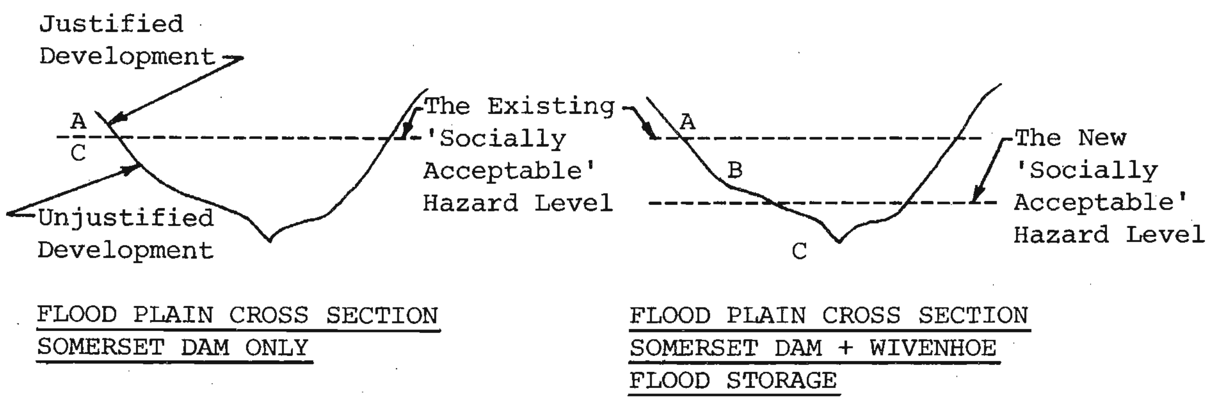


FIGURE A7.1

Developments in areas marked A are above the 'socially acceptable' flood hazard level both before and after the provision of a flood storage at Wivenhoe. The full reduction in flood damage to activities in areas marked A can be claimed as a benefit arising from the structural measure (engineering works). Developments in areas marked B are subject to 'socially unacceptable' flood hazard prior to the provision of the flood storage, but they are above the 'acceptable' flood hazard level after the structural measure is built. In the analysis the full reduction in flood damage is not claimed as a benefit arising from the structural measure. Only that flood damage avoided due to floods equal to or greater than the 'regulatory' flood is counted. Developments in areas marked C are still below the 'socially acceptable' flood hazard level and no flood damage reduction is claimed as a benefit arising from the structural measure.

No flood damage reduction is claimed as a benefit due to the flood storage, therefore, until the storage size is so large that the particular development is at or above the 'socially acceptable' flood hazard level. The total damage reduction arising from the structural measure is claimed as a benefit for developments at or higher than the level of the boundary between areas A and B. No flood damage reduction arising from the structural measure is claimed as a benefit for developments at or lower than the level of the boundary between areas B and C. Between the two boundary lines, i.e. area B only, the flood damage reduction arising from the structural measure, for floods equal to or greater than the 'regulatory' flood, is claimed.

In this analysis, because of insufficient data, one half of the total flood damage reduction in area B is claimed as a benefit.

These benefits and the costs of various flood storages were used to determine revised 'economically justified' optimum sized flood storages for a range of assumed growth rates and discount rates. See Table A7.13.

TABLE A7.13

FLOOD STORAGE CAPACITIES (Ml) BASED ON BENEFITS ONLY TO DEVELOPMENT ABOVE 'ACCEPTABLE' HAZARD LEVEL

'Socially Acceptable' Hazard - Probable Frequency Flood	Growth Rate % p.a.	Discount Rate 8% p.a.	10% p.a.	12% p.a.
1 : 100	0%	980 000	500 000	0
	5%	1 240 000	1 140 000	1 090 000
1 : 50	0%	1 050 000	1 040 000	570 000
	5%	1 230 000	1 140 000	1 120 000
1 : 30	0%	1 080 000	1 045 000	920 000
	5%	1 210 000	1 160 000	1 130 000
1 : 20	0%	1 100 000	1 050 000	1 040 000
	5%	1 190 000	1 180 000	1 130 000
Any Hazard level acceptable	0%	1 100 000	1 090 000	1 050 000
	5%	1 290 000	1 260 000	1 150 000

The Table shows, for example, that if a 1:100 'socially acceptable' flood hazard level, a 10 per cent discount rate and no growth are assumed, a 500 000 megalitres storage can be 'justified'. If development is allowed anywhere in the flood plain for the same discount and growth rate, a storage equivalent to 1 090 000 megalitres can be 'justified'.

Larger flood storages can be 'justified' if benefits to development below the 'socially acceptable' hazard level are included, than would be the case if development had only been permitted in 'socially acceptable' flood hazard areas after the completion of Somerset Dam.

Coping with Development which is still in a flood hazard area

Development in lower levels of the flood plain has occurred, perhaps because of mistaken views as to likely flood damage in the future or of the effectiveness of Somerset Dam in mitigating floods, although a good deal of development had taken place before Somerset Dam was built. On social grounds, the flood damage in these areas should be reduced.

There would appear to be three options available if the concept of a 'socially unacceptable' flood hazard is accepted, namely:

(a) acquisition over time of properties below the 'socially acceptable' flood hazard level after Wivenhoe Dam is built;

(b) building a flood storage large enough to reduce the flood hazard below the acceptable level in all flooded areas; this may not be feasible;

(c) a combination of (a) and (b).

The likely minimum cost solution would be a strategy combining increased storage, above the economically 'justified' optimum storage, and the limited acquisition of property at low levels of the flood plain. The acquisition of properties below flood heights of 'acceptable' hazard would serve the dual purpose of providing a floodway for the passage of the frequent small floods and for flood waters released from the flood storages after a major flooding event.

Commercial and industrial activities in these high hazard areas have access to flood insurance or are a use tolerant to flooding i.e. suffer low flood damage. The siting of commercial and industrial activities in the flood plain in the future should be carefully considered with respect to flood hazard and in most cases these activities should not be allowed below the 'acceptable' flood hazard level. Only residential properties have been considered in the analysis below because they do not have, in general, access to flood insurance and in many cases they are located unwittingly in the flood plain. Residential properties were divided into those flooded above floor level by floods of a particular height and those flooded below floor level for the same flood. The analysis considers the acquisition over time of all residences flooded above floor level as well as all residential property below the particular flood level. The decision to adopt one or the other strategy would depend on both economic and social wellbeing considerations.

Details of development in the Brisbane River Valley flood plain in terms of the number of buildings affected by floods of different heights are set out in Table A7.14.

TABLE A7.14*

ESTIMATES OF FLOOD DAMAGE (MID 1974 MONEY VALUES)
1974 Stage of Development

Flood Height Brisbane City Gauge m	Flooded Area km^2	Buildings Affected	Flood Damage ($M)	
			Direct	Direct + Indirect
2	12	470	8	10
4	57	6 700	67	83
6	102	15 300	173	217
8	153	23 500	288	362
10	205	31 000	426	531

Source: Snowy Mountains Engineering Corporation (23).

*In this and subsequent Tables flood heights on the Brisbane City Gauge refer to the 1974 river conditions and flood plain development and floods are adjusted to a standard 2.0m tide on Port Office Gauge.

Table A7.15 below shows the estimated number of residential properties affected for different probable frequency floods.

TABLE A7.15

RESIDENTIAL DEVELOPMENT AND FLOOD HAZARD
SOMERSET DAM ONLY
(All values interpolated except values for 2 m flood)

Flood Hazard - Probable Frequency Flood	Flood Height Brisbane City Gauge m	Residential Properties Affected		
		Above Floor Level	Below Floor Level	Total
1 : 10	2.0	42	166	208
1 : 20	3.2	950	1 480	2 430
1 : 30	4.1			5 300
1 : 50	5.5			10 000
1 : 100	7.7			17 500

Source: Based on Snowy Mountains Engineering Corporation (23),(31).

See Footnote Table A7.14.

If the 'socially acceptable' flood hazard level chosen is the 1:50 probable frequency flood, then currently there are some 10 000 residential properties subject to 'unacceptable' flood hazard and possibly upwards of 5 000 would be flooded above floor level by the 1:50 probable frequency flood.

Table A7.16 shows that the construction of a flood storage in Wivenhoe Dam would reduce the probable frequency that a flood would reach a particular height on the Brisbane City Gauge and hence would reduce the number of residential properties that would be affected by the level of the 'socially acceptable' flood hazard. The problem is the present and possible future development in areas still below the particular 'acceptable' flood level.

TABLE A7.16

PROBABLE FREQUENCY OF FLOODS
(Log. Pearson Type III Distribution)

Brisbane City Gauge Height AHD	Probable Frequency				
	Somerset Dam only	Somerset Dam + Wivenhoe Dam with Flood Compartments of -Ml			
		500 000	800 000	1 100 000	1 400 000
2 m	1 : 11	1 : 25	1 : 30	1 : 35	1 : 40
4 m	1 : 28	1 : 45	1 : 50	1 : 60	1 : 70
6 m	1 : 60	1 : 70	1 : 95	1 : 135	1 : 200
8 m	1 : 110	1 : 250	v/rare	v/rare	v/rare
10 m	1 : 200	v/rare	v/rare	v/rare	v/rare

v/rare ≫ 1:250

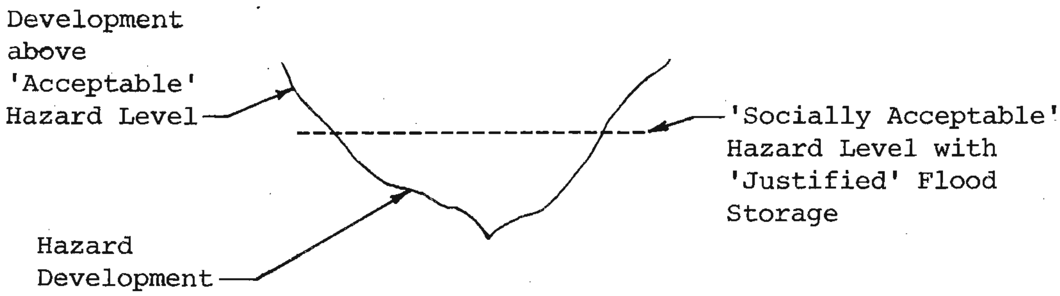
Note: 1:28 represents the probable frequency of such a flood and means that there is one chance in twenty-eight that a flood of that height or higher will occur in any one year.

Source: Snowy Mountains Engineering Corporation (23).
Interpreted from graphs - Irrigation and Water Supply Commission (28).

See Footnote Table A7.14.

Cost Analysis - 'Hazard' Areas

The 'justified' optimum flood storage size was determined for a range of growth and discount rate assumptions and for a range of possible 'socially acceptable' hazard levels. See Figure A7.2.



FLOOD HAZARD LEVELS

FIGURE A7.2

Assuming that the 'socially acceptable' flood hazard level corresponds to the 1:50 probable frequency flood and that there is zero growth and a 10 per cent per annum discount rate, then on economic grounds alone a flood storage in Wivenhoe Dam of 1 040 000 megalitres can be justified and the 'acceptable' flood hazard level will be 2.9 m on the Brisbane City Gauge. See Tables A7.13 and A7.16.

For the areas at hazard below this flood height, an analysis was made on a number of combinations of larger flood storages, and the acquisition over time of the properties still subject to 'unacceptable' degree of hazard. Larger flood storages would reduce the 'socially acceptable' flood hazard height so as to bring the additional properties within areas of 'acceptable' hazard. The results of this analysis are shown in Table A7.17. The acquisition of affected properties was assumed to take place over a period of 10 years if flooded above floor level and over 25 years if flooded below floor level.

The analysis, from which Table A7.17 was compiled, showed that the cost minimising strategy for the case of acquiring properties flooded above floor level by the 1:50 probable frequency flood is to increase the flood storage from 1 040 000 megalitres to 1 150 000 megalitres (new 'acceptable' flood hazard level 2.75 metres) and to acquire about 400 residences located below that level. If all the residences located below the hazard level are acquired, the cost minimising strategy is a flood storage of 1 200 000 megalitres (new 'acceptable' flood hazard level 2.7 metres) and the acquisition of some 1 250 properties. It is assumed that no development is allowed in the future in the areas below the 'regulatory' flood level, i.e. 'socially acceptable' hazard level. It is important to realise that, if all properties below the 'regulatory' flood level are acquired, there is about a 20 per cent chance that properties at the 'regulatory' flood level will be flooded at least once in any ten year period and a 40 per cent chance that they will be flooded at least once in any 25 year period.

TABLE A7.17

COST ANALYSIS - 'HAZARD' AREAS - ILLUSTRATIVE CASE

'1:50 probable frequency flood' as one of 'socially acceptable' hazard, zero growth, 10 per cent discount rate per annum
Optimum Flood storage, 'justified' on economic grounds only = 1 040 000 megalitres

Flood Storage Ml	'Socially Acceptable' Flood Hazard Level m	Extra Storage Cost Present Worth $M	Properties flooded above Floor		All Properties	
			Acquisition Costs Present Worth $M	Total Costs Present Worth $M	Acquisition Costs Present Worth $M	Total Costs Present Worth $M
1 040 000	2.9	0	10.4	10.4	21.7	21.7
1 100 000	2.8	1.4	8.6	10.0	18.4	19.8
1 200 000	2.7	3.8	6.8	10.6	15.3	19.1
1 400 000	2.6	9.8	4.8	14.6	11.5	21.3

See Footnote Table A7.14.

The analysis was repeated for a number of cases. Table A7.18 (p.153) shows the range in acquisition limits, in the estimated number of residences to be acquired and in flood storage volumes for various hazard levels. The Table illustrates that for the discount rates and growth rates considered the flood storage volumes do not vary greatly. Table A7.19 shows benefits and costs and total damage reduction for the case of zero growth and the acquisition of properties flooded above floor levels for various discount rates and 'acceptable' hazard levels.

TABLE A7.19

COSTS AND BENEFITS - ZERO GROWTH
(Residences flooded above floor level acquired only)
Mid 1974 stage of development - zero growth

Discount Rate (% p.a.)	'Socially Acceptable' Hazard	Costs		Equivalent Uniform Annual Justified Benefits ($M)	Sum of Damage Reduction and Damage Avoided in Equivalent Uniform Annual Terms ($M)
		Annual Costs ($M)	Present Worth at 1981/82 ($M)		
8%	None	1.20	15.0	5.00	5.00
	1 : 20	1.20	15.0	4.20	4.95
	1 : 30	1.23	15.4	3.20	4.90
	1 : 50	1.92	24.0	2.25	4.95
	1 : 100	3.04	38.0	1.40	5.35
10%	None	1.55	15.5	4.95	4.95
	1 : 20	1.50	15.0	4.10	5.10
	1 : 30	1.55	15.5	3.15	5.10
	1 : 50	2.31	23.1	2.15	5.10
	1 : 100	3.74	37.4	0.70	5.10
12%	None	1.95	16.3	4.85	4.85
	1 : 20	1.90	15.8	4.05	4.80
	1 : 30	1.84	15.3	2.85	4.35
	1 : 50	3.09	25.8	1.35	4.65
	1 : 100	4.42	36.8	0	4.90

TABLE A7.18

TOTAL COSTS FLOOD STORAGES AND ACQUISITION LEVELS
1974 Development and Money Values
(Above floor level acquisition only)

Discount Rate % p.a.	Growth Rate % p.a.	'Socially Acceptable' Flood Hazard	Flood Storage		Floodway Acquisition			Total Cost Present worth ($M)
			Size Ml	Cost Present worth ($M)	Limit m.	Residential Properties Approx.	Cost Present worth ($M)	
8%	0%	1 : 100	1 200 000	17.1	3.25	1 020	20.9	38.0
		1 : 50	1 100 000	15.0	2.80	490	9.0	24.0
		1 : 30	1 080 000	14.4	2.00	42	1.0	15.4
		1 : 20	1 100 000	15.0	1.20	0	0	15.0
		No restriction	1 100 000	15.0	None	-	-	15.0
	5%	1 : 100	1 240 000	18.1	3.20	950	19.5	37.6
		1 : 50	1 230 000	17.8	2.70	390	8.0	25.8
		1 : 30	1 210 000	17.5	1.95	30	0.8	18.3
		1 : 20	1 190 000	16.9	1.20	0	0	16.9
		No restriction	1 290 000	19.4	None	-	-	19.4
10%	0%	1 : 100	1 120 000	16.5	3.35	1 160	20.9	37.4
		1 : 50	1 080 000	15.5	2.80	490	7.6	23.1
		1 : 30	1 045 000	14.7	2.05	50	0.8	15.5
		1 : 20	1 050 000	15.0	1.25	0	0	15.0
		No restriction	1 090 000	15.5	None	-	-	15.5
	5%	1 : 100	1 140 000	17.0	3.30	1 080	19.5	36.5
		1 : 50	1 140 000	17.0	2.75	440	6.8	23.8
		1 : 30	1 160 000	17.5	1.95	30	0.5	18.0
		1 : 20	1 180 000	18.0	1.20	0	0	18.0
		No restriction	1 260 000	20.5	None	-	-	20.5
12%	0%	1 : 100	1 075 000	16.7	3.40	1 240	20.2	36.8
		1 : 50	1 000 000	15.0	2.95	650	10.8	25.8
		1 : 30	920 000	13.3	2.25	105	2.0	15.3
		1 : 20	1 040 000	15.8	1.25	0	0	15.8
		No restriction	1 050 000	16.3	None	-	-	16.3
	5%	1 : 100	1 090 000	17.1	3.35	1 160	19.8	36.8
		1 : 50	1 120 000	17.9	2.80	490	7.8	25.8
		1 : 30	1 130 000	18.3	2.00	42	0.7	19.0
		1 : 20	1 130 000	18.3	1.20	0	0	18.3
		No restriction	1 150 000	18.8	None	-	-	18.8

See Footnote Table A7.14.

The results indicate that only small differences occur in the flood storage size recommended with changes in the discount rate or the 'socially acceptable' hazard level. There is, however, a major difference in the acquisition limits to provide the cleared floodway and this means large differences in acquisition costs. The Tables show the cost of alternative strategies with respect to 'socially acceptable' flood hazard level.

The analysis indicates that no significant increase in flood storage above that size economically 'justified' can be used as an alternative to the acquisition of properties below the 'socially acceptable' hazard level (compare Tables A7.19 and A7.13), i.e. flood storage in the Dam alone cannot be justified in economic terms as a complete solution to the flood problem in the lower Brisbane Valley. Lower 'acceptable' flood hazard levels can only be attained at increased cost and this increased cost is due to development approved in the past at too low a level in the flood plain.

Table A7.20 (p.155) summarises total costs, flood storage volumes and acquisition limits for a number of possible 'socially acceptable' hazard levels. If growth in the flood plain is allowed, flood storages increase slightly and the level up to which properties should be acquired falls.

TABLE A7.21

ACQUISITION LIMITS, PROPERTIES TO BE ACQUIRED AND FLOOD STORAGE FOR VARIOUS HAZARD LEVELS

'Socially Acceptable' Hazard - Probable Frequency Flood	Case	Range of			
		Acquisition Limit = Height on Brisbane City Gauge m	Residential Properties to be acquired (approx.)	Flood Storage (,000 Ml)	Approx.Expected Residual Equivalent Uniform Annual Residential Damage ($M)
1 : 100	A.F.*	3.20 - 3.40	900 - 1240	1075 - 1240	very small
	All	3.05 - 3.15	2020 - 2290	1300 - 1450	very small
1 : 50	A.F.	2.70 - 2.95	400 - 650	1000 - 1230	0.07
	All	2.60 - 2.75	980 - 1290	1150 - 1325	0.05
1 : 30	A.F.	1.95 - 2.25	35 - 105	920 - 1210	0.14
	All	1.95 - 2.05	175 - 240	1050 - 1210	0.13
1 : 20	A.F.& All	1.20 - 1.25	0	1040 - 1190	0.14
No level set	A.F.& All	None	0	1050 - 1290	0.14

A.F.* = above floor. See Footnote Table A7.14.

Table A7.21 shows for various hazard levels and the two cases of acquisition, the range of acquisition limits, properties to be acquired and flood storages as well as an estimate of mean residual annual residential damage.

TABLE A7.20

SUMMARY - FLOOD STORAGE VOLUMES, COSTS, ACQUISITION LIMITS, ETC.
(Above floor level acquisition only)

'Socially Acceptable' Hazard	Flood Storage Ml	Storage Costs Present Worth at 1981/82 ($M)	Acquisition Limit on Brisbane City Gauge	Acquired Residential Properties	Acquisition Costs Present Worth at 1981/82 ($M)	Total Cost Present Worth at 1981/82 ($M)
1 : 100	1 075 000-1 240 000	16.7 - 18.1	3.20 - 3.40	900 - 1 240	19.5 - 20.2	36.2 - 38.3
1 : 50	1 000 000-1 230 000	15.0 - 17.8	2.70 - 2.95	400 - 650	8.0 - 10.8	23.0 - 28.6
1 : 30	920 000-1 210 000	13.3 - 17.5	1.95 - 2.25	35 - 105	0.8 - 2.0	14.1 - 19.5
1 : 20	1 040 000-1 190 000	15.8 - 16.9	1.20 - 1.25	0	0	15.8 - 16.9
None	1 050 000-1 290 000	16.3 - 19.4	None	0	0	16.3 - 19.4

See Footnote Table A7.14.

The analysis shows the conflict between costs and the 'acceptable' level of hazard. It shows the economic and social advantages of preserving in the flood plain a 'floodway' free of development. The storage size that could be justified on the basis of the analysis is in the range 1 000 000 - 1 300 000 megalitres.

<u>Uncertainty Reconsidered</u>

The analysis for 'hazard' areas has assumed that the chance that a flood of a certain height will occur is known with complete certainty. As discussed previously, this is not the case. If uncertainty is included in the analysis it will have an increasingly significant effect as the 'socially acceptable' hazard decreases, i.e. as the emphasis changes to the rarer flooding events. A precise specification of the necessary level below which properties should be acquired, corresponding to a particular height of flood at the Brisbane City Gauge, will not be possible.

The analysis has shown that a flood storage in the range 1 000 000 - 1 300 000 megalitres can be justified on economic and social wellbeing criteria. The justification for an increase in flood storage on this basis depends on the aversion to uncertainty and the importance of avoiding uncertainty. An increase in flood storage should also be made to allow for human error in the interpretation of information received during the flood and for possible malfunction of equipment during flooding.

The uncertainty analysis indicates that a case could be made for a small increase in flood storage.

REFERENCES

1. Gipps, R. deV. (1974), 'Water Resources and their Availability in the Moreton Region', Proc. I.E.A. Symposium on 'Water Resources in the Moreton Region', Sept.

2. Cossins, G. (1974), 'Forecasting Water Consumption for the Brisbane Conurbation', Proc. I.E.A. Symposium on 'Water Resources in the Moreton Region', Sept.

3. Beattie, D.W. (1975), 'Water Resources and Management Problems in the Moreton Region', Water Research Foundation of Aust., Report No. 46, Nov.

4. Co-ordinator-General's Department (1971), 'Report on Proposed Dam on the Brisbane River at Middle Creek or alternatively Wivenhoe and Flood Mitigation for Brisbane and Ipswich'. 2 vols. June.

5. Department of Local Government (1970), 'Report on Proposed Dam on Albert River at A.M.T.D. 12'.

6. Brisbane City Council (1971), 'Report on the Augmentation of the Water Supply to the Brisbane Conurbation', July, unpublished.

7. Gipps, R. deV. (1975), 'Wivenhoe Dam - Its Role in Water Supply and Flood Mitigation', Water Research Foundation of Australia, Report No. 46, 'Management of Water Resources in the Moreton Region'.

8. Shepherd, E.M. and Meredith J.M. (1973), 'Feasibility Study of the Proposed Wivenhoe 500 MW Pumped Storage Hydro-Electric Scheme'. Report prepared for State Electricity Commission, Brisbane, May, unpublished.

9. Swindon, V.G. (1971), 'ANZAAS Geological Excursion Handbook', May.

10. Hubble, G.D., Thompson, C.H. and Beckman, G.G. (1972), 'Soils of the Moreton Region', C.S.I.R.O. Division of Soils.

11. Department of Primary Industries (1974), 'Moreton Region - Non-Urban Land Suitability Study', Part 1, Tech. Bull. No. 11, Div. of Land Utilisation, Sept.

12. Department of Aboriginal and Islanders Advancement (1975). Unpublished memorandum to the Co-ordinator-General's Department.

13. Co-ordinator-General's Department (1973), 'Moreton Region - Outdoor Recreation', Dec.

14. Department of Primary Industries (1975). Unpublished memorandum to Co-ordinator-General's Department.

15. Department of Primary Industries (1975). Unpublished report to Co-ordinator-General's Department.

16. Sattler, P.S. (1972), 'Wivenhoe Pumped Storage Hydro-Electric Scheme - Environmental Aspects of Proposed Power House Construction'. Report prepared for Co-ordinator-General's Department, Dec. Unpublished.

17. Co-ordinator-General's Department (1973), 'Moreton Region Water Supply', Brisbane.

18. Co-ordinator-General's Department (1976). Unpublished internal report.

19. Cossins, G. (1974), 'Anatomy of Urban Water Supply', Technical Papers, I.E.Aust (Qld. Div.), Sept.

20. Irrigation and Water Supply Commission (1976), 'Yield Studies for Wivenhoe Dam', Nov., unpublished.

21. Irrigation and Water Supply Commission (1976), 'Preliminary Design of the Proposed Wivenhoe Dam on the Brisbane River', Interim Report, Jan., unpublished.

22. National Water Council (U.K.) (1976), 'Paying for Water'.

23. Snowy Mountains Engineering Corporation (1975), 'Brisbane River Flood Investigations', Report prepared for Cities Commission, Nov.

24. 'January 1974 Floods Moreton Region' (1974), Proc. of Symposium, I.E.Aust. (Qld. Div.), Brisbane.

25. 'Management of Water Resources in the Moreton Region' (1975), Proc. of Symposium, Report No. 46, W.R.F.(Aust.), Brisbane, Nov.

26. Cossins, G. (1976), 'Flood Envelopes and Frequencies for the Brisbane River', Proc. Hydrology Symposium, I.E.Aust.

27. Brisbane City Council (1976). Memorandum to Co-ordinator-General's Department, March, unpublished.

28. Irrigation and Water Supply Commission (1976). Memorandum to Co-ordinator-General's Department, May, unpublished.

29. Kates, R.C. (1962), 'Hazard and Choice Perception in Flood Plain Management', Uni. of Chicago, Dept. of Geography, Research Paper No. 78.

30. Grigg, T.J. (1976), 'Multi-Objective Planning', Proc. of Symposium 'Flood Plain Management' I.E.Aust. (Qld. Div.), Brisbane, June.

31. Snowy Mountains Engineering Corporation (1976), 'Stage Damage Curves for the Brisbane River', Supplementary Report prepared for Co-ordinator-General's Department, July, unpublished.

32. Valuer-General's Department (1976). Report to Co-ordinator-General's Department, October, unpublished.

33. James and Lee (1971), 'Economics of Water Resources Planning', McGraw-Hill Book Company, New York.

34. Water Resources Council (1973), 'Principles and Standards for Planning Water and Related Land Resources', in Federal Register, Sept. 10, 1973, 38, 24778-869.

35. Meredith, J.M. (1971), 'Feasibility Study of Proposed Wivenhoe Pumped Storage Hydro-Electric Scheme', Report prepared for Co-ordinator-General's Department, April, unpublished.

36. Bobée, B. (1975), 'The Log Pearson Type 3 Distribution and its Application in Hydrology', Water Resources Research, Vol. 11, No. 5.

37. Kite, G.W. (1975), 'Confidence Limits for Design Events', Water Resources Research, Vol. 11, No. 1.